

Chapter 3 Affected Environment

Section 1502.15 of the CEQ NEPA regulations (40 CFR parts 1500-1508) direct that “an environmental impact statement shall succinctly describe the environment of the area(s) to be affected or created by the alternatives under consideration. The descriptions shall be no longer than is necessary to understand the effects of the alternatives. Data and analyses in a statement shall be commensurate with the importance of the impact, with less important material summarized, consolidated, or simply referenced. Agencies shall avoid useless bulk in statements and shall concentrate effort and attention on important issues. Verbose descriptions of the affected environment are themselves no measure of the adequacy of an environmental impact statement.”

This affected environment section contains succinct descriptions of the resources and issues identified as important to predicting the direct, indirect, and cumulative impacts that will accrue from the proposed action. The topics in this section are arranged in the same order they are treated in the environmental consequences section that follows: marine mammals, target fish species, non-specified fish species, forage fish, prohibited species, ESA listed Pacific salmon, seabirds, marine benthic habitat, ecosystem, State managed fisheries, management complexity and enforcement issues, and socio-economic issues.

References to original literature are made throughout the section to identify scientific sources and guide readers to further information. All references called out throughout chapters 1, 2, 3, and 4 of this document are listed in chapter 7 of this document. Each reference contains information necessary to find the respective paper, report, journal article, or book, following standard library citation format. Any reader desiring to access one of the references given should be able to read or borrow a copy from a public library. Resource libraries located in Alaska and the Northwest such as the NMFS Alaska Fisheries Science Center Library in Seattle, Washington, or the Auke Bay Fisheries Laboratory near Auke Bay, Alaska, the State Library in Juneau, Alaska, and the libraries at the University of Alaska and the University of Washington, will be more likely to have these particular references on their shelves. Other libraries are able to get these references through interlibrary loan systems.

3.1 Marine Mammals

Because of combinations of bathymetric and oceanographic features, the Bering Sea and Aleutian Island (BSAI) and Gulf of Alaska (GOA) are among the world’s most productive ecosystems, and supports a rich assemblage of marine mammals (Loughlin, *et al.*, 1999). Marine mammals occur in diverse habitats, including deep oceanic waters, the continental slope, and the continental shelf (Lowry *et al.*, 1982). In the areas fished by commercial groundfish fleets, twenty-six species of marine mammals are present from the orders Pinnipedia (seals, sea lion, and walrus), Carnivora (sea otter and polar bear), and Cetacea (whales, dolphins, and porpoises) (Lowry and Frost 1985). Most species are resident throughout the year, while others seasonally migrate into or out of the management areas. Following are descriptions of their distribution, population status, abundance, habitat, diet, and known sources of anthropogenic mortality.

3.1.1 Steller Sea Lion

The Steller sea lion (*Eumetopias jubatus*), also found in the literature as Steller’s sea lion and northern sea lion, probably evolved in the North Pacific at least 3-4 million years ago (Repenning, 1976). Steller sea lions are members of order the Pinnipedia, family Otariidae (composed of fur seals and sea lions), subfamily Otariinae, a group of five sea lion species (California (*Zalophus californianus*), Steller, southern (*Otaria*

bryonia), Australian (*Neophoca cinerea*), and New Zealand (*Phocartos hookeri*)) mostly distributed in temperate and subpolar waters.

3.1.1.1 Distribution

The Steller sea lion ranges along the North Pacific Ocean rim from northern Japan to California (Loughlin *et al.*, 1984), with centers of abundance and distribution in the GOA and Aleutian Islands, respectively (Figure 3.1-1). The northernmost breeding colony in the Bering Sea is on Walrus Island near the Pribilof Islands, and in the GOA on Seal Rocks in Prince William Sound, the northern most of all sea lion rookeries (Kenyon and Rice, 1961).

In general sea lions seem to have a high degree of site fidelity, returning to breed at or near their natal rookeries (Loughlin, 1997; Raum-Suryan *et al.*, submitted). Tagged and branded individuals have been seen at distances up to 1784 km from their natal rookeries, but once they approach adulthood they generally remain within 500 km of their natal rookery (Raum-Suryan *et al.*, submitted).

3.1.1.2 Population Status and Trends

In November 1990, the NMFS listed Steller sea lions as “threatened” range-wide under the U.S. Endangered Species Act (55 *Federal Register* 49204, November 26, 1990) in response to a population decrease of 50% - 60% during the previous 10 - 15-year period. Several years later, two population stocks were identified, based largely on differences in genetic identity, but also on regional differences in morphology and population trends (Bickham *et al.*, 1996; Loughlin, 1997). The western stock, which occurs from 144° W long. (approximately at Cape Suckling, just east of Prince William Sound, Alaska) westward to Russia and Japan, was listed as “endangered” in June 1997 (62 *Federal Register* 24345, May 5, 1997). The eastern stock, which occurs from southeast Alaska southward to California, remains classified as threatened.

3.1.1.2.1 Western Stock

Population assessment for Steller sea lions has been achieved primarily by aerial surveys and on-land pup counts. Historically, this included surveys of limited geographical scope in various portions of the species’ range, in many cases conducted using different techniques, and occasionally during different times of year. Consequently, reconstructing population trends for Steller sea lions from the 1970s and earlier, and over a large geographical area, such as the Western Stock in Alaska, includes a patchwork of regional surveys conducted over many years.

Aerial surveys conducted from 1953 through 1960 resulted in combined counts of 170,000 to 180,000 Steller sea lions in what we now define as the Western Stock in Alaska (Mathisen, 1959; Kenyon and Rice, 1961). Surveys during 1974-1980 suggested an equivocal increase to about 185,000, based on maximal counts at sites over the same area, as summarized by Loughlin *et al.* (1984). It was concurrent with the advent of more systematic aerial surveys that population declines were first observed. Braham *et al.* (1980) documented declines of at least 50% from 1957 to 1977 in the eastern Aleutian Islands, the heart of what now is the Western Stock. Merrick *et al.* (1987) estimated a population decline of about 50% from the late 1950s to 1985 over a much larger geographical area, the central Gulf of Alaska through the central Aleutian Islands, although this still included a patchwork of regional counts and surveys (Figures 3.1-1, 3.1-2). The population in the Gulf of Alaska and Aleutian Islands declined by about 50% again from 1985 to 1989, or an overall decline of about 70% from 1960 to 1989 (Loughlin *et al.*, 1992).

Much of the population trend analyses during recent years has focused on “trend sites” as espoused by the Steller Sea Lion Recovery Team (NMFS 1992b, NMFS 1995a). Trend sites are those rookeries and haul-out sites surveyed consistently from the mid 1980s to the present, thus allowing analysis of population trends on a decadal scale. Trend sites include about 75% of animals observed in recent surveys (Strick *et al.*, 1997; Sease *et al.*, 1999; Sease and Loughlin, 1999; Sease *et al.*, 2001). At 82 rookery and haul-out trend sites in the western stock, the June 2000 count represented declines of 10.3% from 1998, 17.5% from 1996, and 40.0% from 1990 (Figure 3.1-1) (Sease *et al.*, 2001). The average annual rate of decline has been consistently around 5% during the 1990s (Strick *et al.*, 1997; Sease *et al.*, 1999; Sease and Loughlin, 1999; Sease *et al.*, 2001).

The population decline for the Western Stock in Alaska has been apparent in all regions, although not at the same rate. The decline was first observed in the eastern Aleutian Islands (Braham *et al.*, 1980). During subsequent years the decline spread into adjacent regions in the Aleutian Islands and Gulf of Alaska (Merrick *et al.*, 1987). In the eastern Aleutian Islands, the rate of decline lessened and by 1989 or 1990 the population there appeared to stabilize, but at very low levels (Figure 3.1-2). Since 1975 there has been a steady rate of decline of 6% a year or greater, with an additional drop of about 8.7% per year during the late 1980s when the population from the Kenai Peninsula to Kiska Island in the central Aleutian Islands declined at about 15.6% per year (York *et al.*, 1996). Other regions have demonstrated short periods of stability within a general declining trend. With the exception of the differentiation between the eastern and western stocks, however, these regional boundaries are not based on ecological or other biological parameters, and differences in regional trends should be interpreted with caution.

In most years, pups within the Western Stock in Alaska have been counted only at selected rookeries, and on an alternating schedule to minimize potential cumulative effects of disturbance. Range-wide survey efforts included pup counts at virtually all Western Stock rookeries in Alaska in 1998, and all except the Near Islands in the western Aleutian Islands in 1994 (Strick *et al.*, 1997; Sease and Loughlin, 1999). Pup counts in the western stock in Alaska (excluding the western Aleutian Islands) declined by 19.0% from 1994 to 1998. In the western Aleutian Islands, pup numbers declined 18% from 1997 to 1998, the only years for which comprehensive comparison is possible (Figure 3.1-3). Recent pup counts in 2000 and 2001 from Seguam Island to Prince William Sound were similar in magnitude to those conducted in 1998 (NMFS NMML data, unpublished).

3.1.1.2.2 Eastern Stock

Loughlin *et al.* (1992) described southeast Alaska as the only region of Alaska in which the Steller sea lion population appeared to be stable in 1989, even though numbers of non-pup sea lions (adults and juveniles combined) in southeast Alaska increased by about 16% from 1985 to 1989, or by an average of 3.5% to 4.0% per year. Calkins *et al.* (1999) estimated that the Steller sea lion population in southeast Alaska increased by an average of 5.9% per year from 1979 to 1997, based on counts of pups at the three rookeries in the region. From 1989 to 1997, however, pup numbers increased by only 1.7% and counts of non-pups at 12 index sites were stable (average change of +0.5% per year). The Steller Sea Lion Recovery Team employed a different set of index, or “trend,” sites for monitoring population status (NMFS, 1992b; NMFS, 1995a). Counts of non-pup sea lions at the three rookeries and ten haul-outs sites showed an overall increase of 29.3% from 1990 to 2000, or an average annual increase of 1.9% (Sease *et al.*, 2001). Despite differences in individual index sites or model type (e.g., based on counts of pups versus non-pups), the conclusion is that numbers of Steller sea lions in southeast Alaska are stable or increasing slightly (Figure 3.1-4).

Steller sea lions in southeast Alaska are not an isolated stock, as demonstrated by genetic data and by the movement of branded and tagged animals from southeast Alaska to British Columbia and Washington (Raum-Suryan *et al.*, submitted). The number of non-pup sea lions in British Columbia is similar to the number in southeast Alaska, and increasing by about 2.5% per year during the last decade (Figure 3.1-5). Numbers of pups in British Columbia have increased by about 1.5% per year during the same time (personal communication from P. Olesiuk, Pacific Biological Laboratory, Nanaimo, British Columbia, V9R 5K6). Counts of Steller sea lions in Oregon and northern California have been stable during recent decades at about a third as many animals as in either British Columbia or southeast Alaska. Numbers in central and southern California have been small, but decreasing at about 4.5% - 5.0% per year since 1982 or as much as 10% per year since 1990 (NMFS, 1995; Calkins *et al.*, 1999; Ferrero *et al.*, 2000, Angliss *et al.*, 2001). Despite the observed declines in southern and central California, the Eastern Stock as a whole is stable or increasing slowly.

3.1.1.3 Reproduction and Growth

Steller sea lions have a polygynous reproductive system in which a single male may mate with multiple females. Males establish territories in May in anticipation of female arrival (Pitcher and Calkins, 1981). Mating occurs on land (or in the surf or intertidal zones), thus males are able to defend territories and thereby exert at least partial control over access to adult females and mating privileges. The pupping and mating season is relatively short and synchronous, probably due to the strong seasonality of the environment and the need to balance aggregation for reproductive purposes with dispersion to take advantage of distant food resources (Bartholomew, 1970). In late May and early June, adult females arrive at the rookeries, where pregnant females give birth to a single pup (twinning is rare). Viable births begin in late May and continue through early July. The sex ratio of pups at birth is approximately 1:1, though biased toward slightly greater production of males (e.g., Pike and Maxwell, 1958; Lowry *et al.*, 1982; NMFS, 1992b). Pupping is highly synchronous throughout the sea lion range between the Aleutian Islands and California, with a median pupping date of 12-13 June (Bigg 1985, Merrick 1987). There is evidence that pupping dates have become later at Sugarloaf and Fish Island rookeries (Pitcher *et al.*, 1996). Because timing of pupping depends upon maternal condition, this change may reflect changing environmental conditions, or changing maternal age structure.

Merrick *et al.* (1995) compared pup sizes at different sites where Steller sea lion populations were either decreasing or increasing, to determine if pup size or growth may be compromised in decreasing populations. Their results were not consistent with that hypothesis; rather, they found that pups about two to four weeks of age weighed more at sites in the Aleutian Islands and GOA than in southeast Alaska or Oregon. Fadely and Loughlin (2001) also found that these pups did not weigh greater than expected based on body length, such that they were larger overall. These size differences may arise through different growth rates, as no significant differences have been found among neonatal mass among rookeries (Brandon and Davis, 1999; Adams, 2000). Brandon and Davis (1999) and Adams (2000) found that pups at rookeries in areas of decline grew faster than pups from southeast Alaska. As there were no differences in milk or energy intake among pups at these rookeries, differences in growth rates may be attributable to differences in pup activity (Adams, 2000), time spent fasting between suckling bouts, or other physiological costs. These observed differences indicate that at least this phase of reproduction may not be affected; that is, if females are able to complete their pregnancy and give birth, then the size of those pups does not appear to be compromised. Possible alternative explanations for the observed size differences are that pups were measured at different ages (i.e., pups in the GOA and Aleutian Islands may have been born earlier and therefore were older when weighed), or that over time, harsher environmental conditions in the Aleutian Islands of the GOA have selected for

larger pup size. Pup condition, measured as the ratio of observed body mass to that expected based on length, seems to be a reasonable index of condition related to survival (Trites and Jonker, 2000). For the pups aged between 2 and 4 weeks, there was no general relationship between pup condition and pup numbers or magnitude of decline at rookeries, though the poorest average pup conditions during the late 1990s were associated with areas of greatest decline (Fadely and Loughlin, 2001). There also was evidence that pup condition was poorest during weak depressions of the Aleutian Low, and better when the Aleutian Low was stronger.

Mothers nurse pups during the day, staying with a pup for the first week, then go to sea on foraging trips. Maternal attendance patterns seem to vary over the range, with the average length of foraging trips during lactation being about 24 hours to two days at the southernmost rookery at Año Nuevo Island, California (Higgins *et al.*, 1988; Hood and Ono, 1997), about 25 hours at Lowrie Island, 19 hours at Fish Island, 11 hours for Chirikof Island, and 7 hours in the Aleutian Islands (Brandon and Davis, 1999). Pups generally are weaned before the next breeding season, but it is not unusual for a female to nurse her offspring for a year or more. The ramifications of nursing a pup beyond a year on pupping frequency, or survival of a second pup, are unknown.

The length of the nursing period may be an important indicator of the female's condition and ability to support her pup, and the pup's condition at weaning (and hence, the likelihood that the pup will survive the post weaning period). Steller sea lion weaning takes place away from the rookeries, over a period of time, and thus has not been directly observed in Alaska. Thorsteinson and Lensink (1962) suggested that nursing of yearlings was common at Marmot Island in 1959. Pitcher and Calkins (1981) suggested that it is more common for pups to be weaned before the end of their first year, but they also observed nursing juveniles (aged 1 - 3). Porter (1997) distinguished metabolic weaning (i.e., the end of nutritional dependence of the pup or juvenile on the mother) from behavioral weaning (i.e., the point at which the pup or juvenile no longer maintains a behavioral attachment to the mother). He also suggested that metabolic weaning is more likely a gradual process occurring over time and more likely to occur in March-April, preceding the next reproductive season. In many otariids, the length of the lactation period varies among individuals and 'weaning' occurs over a period of time, rather than at a single point of time as with phocids (Lee *et al.*, 1991). Using an allometric relationship between weaning mass and maternal mass for otariids (Kovacs and Lavigne, 1992), and assuming a maternal mass of 530 lbs. (240 kg) (midpoint of range of maternal masses, 386.8 - 663 lbs (175 - 300 kg) (Calkins and Pitcher 1982), Steller sea lions could be expected to wean when achieving a body mass of 159 - 183 lbs (72 - 83 kg). According to growth data of Calkins and Pitcher (1982), this is achieved at an age of 11 months, and assuming a median pupping date of June 12, is an age reached in mid-May. A weaning age of 11 months was also used in analyses of comparative mammalian weaning by Lee *et al.* (1991). The transition to nutritional independence may, therefore, occur over a period of months as the pup begins to develop essential foraging skills, and depends less and less on the adult female. The length of the nursing period may also vary as a function of the condition of the adult female. The nature and timing of weaning is important because it determines the resources available to the pup during the more demanding winter season and, conversely, the demands placed on the mother during the same period. A bioenergetic model suggested that a 10 year old female nursing a pup in the spring had to consume twice as much energy as a same age female without a pup (Winship, 2000). The maintenance of the mother-offspring bond may also limit their distribution or the area used for foraging (see Section 3.1.6).

Relatively little is known about the life history of sea lions during the juvenile years between weaning and maturity. Female growth is asymptotic, and reaches 87% of the asymptote during their third year (Winship *et al.*, 2001), a size typically associated with puberty in female pinnipeds (Laws, 1956). Pitcher and Calkins (1981) found that females reach sexual maturity between 2-8 years of age, with an average age of first

pregnancy at 4.9 ± 1.2 years, and may breed into their early twenties. The available literature indicates an overall reproductive (birth) rate on the order of 55% - 70% or greater (Pike and Maxwell, 1958; Gentry, 1970; Pitcher and Calkins, 1981; Pitcher *et al.*, in press). York (1994) derived age-specific fecundity rates based on data from Calkins and Pitcher (1982). Those rates illustrate a number of important points and assumptions. First, the probability of pupping is rare (about 10%) for animals 4 years of age or younger. Second, maturation of 100% of a cohort of females occurs over a prolonged period which may be as long as 4 years (starting at age 3 or 4). Third, the reported constancy of fecundity extending from age 6 to 30 indicates that either senescence has no effect on fecundity, or our information on fecundity rates is not sufficiently detailed to allow confident estimation of age-specific rates for animals older than age 6. Given the small size of the sample taken, the latter is a more likely explanation for such constancy.

For mature females, the reproductive cycle includes mating, gestation, parturition, and nursing or post-natal care. Mating occurs about one to 2 weeks after giving birth (Gentry 1970). Copulation may occur in the water, but mostly occurs on land (Pitcher and Calkins, 1998; Gentry, 1970; Gisiner, 1985). The gestation period is probably about 50 to 51 weeks, but implantation of the blastocyst is delayed until late September or early October (Pitcher and Calkins, 1981). Due to delayed implantation, the metabolic demands of a developing fetus are not imposed on the female until well into fall and early winter. After parturition (birth), females nurse their pups over a period of months to several years. The reproductive success of an adult female is determined by a number of factors within a cycle and over time through multiple cycles. The adult female's ability to complete this cycle successfully is largely dependent on the resources available to her. While much of the effort to explain the Steller sea lion decline has focused on juvenile survival rates, considerable evidence suggests that decreased reproductive success may also have contributed to the decline.

- Young females collected in the 1970s were larger than females of the same age collected in the 1980s (Calkins *et al.*, 1998). As size, as well as age, may influence the onset of maturity, females in the 1980s would also be more likely to mature and begin to contribute to population productivity at a later age.
- Pitcher *et al.* (1998) provide data from the 1970s and 1980s that suggest a high pregnancy rate after the mating season (97%; both periods), which declined to 67% for females collected in the 1970s and 55% for females collected in the 1980s. These changes in pregnancy rate suggest a high rate of fetal mortality that could be a common feature of the Steller sea lion reproductive strategy (i.e., may occur even when conditions are favorable and population growth is occurring), but is more likely an indication of stress (possibly nutritional) experienced by individual females.
- The observed differences in late pregnancy rates (67% in the 1970s and 55% in the 1980s) were not statistically significant. However, the direction of the difference is consistent with the hypothesis that reproductive effort in the 1980s was compromised.
- Pitcher *et al.* (1998) did observe a statistical difference in the late season pregnancy rates of lactating females in the 1970s (63%) versus lactating females in the 1980s (30%). This difference indicates that in contrast to lactating females in the 1970s, lactating females in the 1980s were less able to support a fetus and successfully complete consecutive pregnancies.

Male growth is also asymptotic, but constant until about year 6 and thus males grow at a greater rate for a longer period than do females (Winship *et al.*, 2001). Males also reach sexual maturity at about 3 - 8 years old, but do not have the physical size or skill to obtain and keep a breeding territory until they are nine years of age or older (Pitcher and Calkins, 1981). A sample of 185 territorial males from Marmot, Atkins,

Ugamak, Jude, and Chowiet Islands in 1959 included animals 6 - 17 years of age, with 90% from 9 - 13 years old (Thorsteinson and Lensink, 1962). Males may return to the same territory for up to 7 years, but most return for no more than 3 years (Gisiner, 1985). During the breeding season, males may not eat for 1 to 2 months. The rigors of fighting to obtain and hold a territory and the physiological stress of the mating season reduces their life expectancy. Males rarely live beyond their mid-teens, while females may live as long as 30 years.

3.1.1.4 Survival

Much of the recent effort to understand the decline of Steller sea lions has been focused on juvenile survival, or has assumed that the most likely proximate explanation is a decrease in juvenile survival rates. This contention is consistent with direct observations and a modeling study, and is consistent with the notion that juvenile animals are less adept at avoiding predators and obtaining sufficient prey for growth and survival.

The direct observations consist of low resighting rates at Marmot Island of 800 pups tagged and branded at that site in 1987 and 1988 (Chumbley *et al.*, 1997) and observations of relatively few juveniles at Ugamak Island (Merrick *et al.*, 1988). The low resighting rates do not themselves confirm that the problem was a corresponding drop in juvenile survival, but only that many of the marked animals were lost to the Marmot Island population. Migration to other sites where they were not observed is a possibility, but unlikely given the observations of relatively high site fidelity of animals returning to breed at their natal site. If the “loss” of these animals is viewed in the context of the overall sea lion decline in the central GOA (from 1976 to 1994 the number of non-pups counted at Marmot Island declined by 88.9% and by 76.9% at the 14 other trend sites in the Gulf; Chumbley *et al.*, 1997), then a significant increase in juvenile mortality is a much more plausible conclusion.

Modeling by York (1994) suggests that the observed decline in sea lion abundance in the GOA may have been due to an increase in juvenile mortality. York used the estimated rate of decline between the 1970s and the 1980s, and the observed shift in the mean age of adult females (3 years of age) to explore the effects of changes in adult reproduction, adult survival, and juvenile survival. While she pointed out that the observed decline did not rule out all other possible explanations, she concluded that the observed decline is most consistent with a decrease in juvenile survival on the order of 10% - 20% annually.

However, juvenile survival is not assumed to be the only factor influencing the decline of the western population of Steller sea lions. Evidence indicating a decline in reproduction was presented in the previous section. In addition, changes in adult survival may also have contributed to the decline. At present, survival rates for adult animals can not be determined with sufficient resolution to determine if those rates have changed over time or are somehow compromised to the extent that population growth and recovery are compromised.

3.1.1.5 Age distribution

Two life tables have been published with age-specific rates. The first was from Calkins and Pitcher (1982) and was based on sea lions killed in the mid to late 1970s. York (1994) created a second life table using a Weibull model from the same data from Calkins and Pitcher (1982). A comparison of data collected between the 1970s and the 1980s (Calkins and Goodwin 1988) showed a 1.55 year increase in the mean age of reproductive females.

Both samples of sea lions were from the same area but collected over different time periods. Independent of the samples were observations of the rate of decline of the population. These three pieces of information were combined (York 1994) to suggest that increased juvenile mortality may have been an important proximate factor in the decline of Steller sea lions. That is, such a shift in mean age would occur as the adult population aged without expected replacement by recruitment of young females.

3.1.1.6 Prey and Foraging Behavior

3.1.1.6.1 Methodology and potential biases

Historically, diet studies on marine mammals were based on the remains of prey in the stomach contents of the predator. Currently, the primary method of identifying prey species consumed by pinnipeds is through analysis of bony remains in fecal (scat) collections. The interpretation of predator diet through the use of scat was first developed for terrestrial studies and has been adapted for use in marine mammal trophic studies over the past two decades. Scat is a reliable tool for monitoring seasonal and temporal trends in predator diets without the need to euthanize the animal.

Typically, the rank importance of any given prey species in marine mammal diet studies is based on some combination of two factors: the number of individuals of a particular species represented across all samples (prey number); and the number of samples containing that species across all samples containing prey remains (frequency of occurrence). All methods of diet evaluation (stomachs, lavage, regurgitations, scat, enema, fatty acids, and stable isotopes analyses) in marine mammals have their own set of biases that variably affect estimates of prey volume, weight, number, rank and frequency of occurrence (Fitch and Brownell, 1968; Perrin *et al.*, 1973; Jobling and Breiby, 1986). For instance, stomach contents from an individual animal may represent an accumulation of a number of meals over an extended period of time since certain prey parts such as squid beaks or large fish bones get trapped in stomach folds where they digest very slowly, or accumulate until regurgitated. An accumulation of prey parts predictably overestimate the importance of some prey types over others. Regurgitations (spewings) represent a very small portion of the overall diet and primarily that of the largest prey items consumed. Scat remains by comparison typically represent meals eaten 12 - 72 hours prior and tend to underestimate the size of prey consumed since small items pass through the digestive tract more readily (and with less erosion) than large items (Sinclair *et al.*, in prep.). Accordingly, diet studies should be interpreted with consideration of the method used to collect prey samples.

Steller sea lions eat a broad range of prey that vary in adult body size from approximately 10-80 cm in body length. The most recent diet study of the western stock (Sinclair and Zeppelin, submitted) indicates that prey remains in scat are primarily from late stage juvenile to adult size fish. However, these estimates are qualitatively based on visual comparison with museum reference specimens. To date, estimates of prey size have remained qualitative due to the limited number of intact otoliths (fish earbones) recovered from Steller scats. Otoliths recovered from pinniped stomachs and scats are typically used to estimate size of fish prey using otolith to body length regressions. However, relatively few otoliths are recovered in Steller sea lion scats and those that are found are usually highly degraded due to erosion in the stomach. Other skeletal remains are found in Steller sea lion scat in greater abundance and in better condition than otoliths, but until recently (Zeppelin *et al.*, in prep), no technique existed to quantify bone size to fish length.

Zeppelin *et al.* (in prep) developed regressions to estimate fish length using six diagnostic bones (other than otoliths) from Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), and Atka mackerel (*Pleurogrammus monopterygius*). For all species and all elements, regressions showed a high

degree of correlation between the size of the element and the fork length of prey ($r^2 \geq 0.85$). Fork length of prey consumed by Steller sea lions was predicted by applying these regression models to skeletal structures recovered from scats collected during 1998 and 1999 across the range of the western stock, confirming qualitative estimates that Steller sea lions largely consume adult fish (Sinclair and Zeppelin, submitted). These regressions will eventually allow quantitative comparisons between the size of prey consumed by Steller sea lions and the commercial fish catch in Bering Sea and Gulf of Alaska.

3.1.1.6.2 Foraging Distribution and Depths

At least three types of telemetry are (or have been) used to study sea lion foraging. Very high frequency (VHF) telemetry can be used to determine presence or absence of an animal and, to some extent, animal location and whether it is on land or in the water. The use of VHF telemetry to determine the presence or absence of an animal can be used to infer the occurrence and length of foraging trips (e.g., Brandon, 2000; Merrick and Loughlin, 1997), and movement patterns between sites that can be monitored manually, remotely, or automatically by VHF receivers.

Satellite-linked telemetry is being used to determine animal location and, when coupled with time-depth recorders, diving patterns (e.g., Merrick *et al.*, 1994). Satellite-linked telemetry provides an opportunity to collect information on animal location without having to recapture the animal to collect stored data. At present, satellite-linked telemetry is the most cost-effective means of assessing the distribution of foraging animals and thereby determining those regions that are critical for Steller sea lions.

Stomach telemetry is being developed and offers an opportunity to determine when an animal has consumed prey, rather than requiring the investigator to infer feeding from diving behavior. Stomach telemetry, in combination with satellite-linked telemetry, may provide greater understanding of foraging behavior and discrimination of at-sea activities that may or may not be related to foraging (Andrews, 1998).

Steller sea lion foraging distribution is based on sightings at sea or observations of foraging behavior (or presumed foraging behavior) in areas such as the southeastern Bering Sea (Fiscus and Baines, 1966; Kajimura and Loughlin, 1988; NMFS unpublished data¹ from the Platform-of-Opportunity Program [POP]), records of incidental take in fisheries (Perez and Loughlin, 1991), and satellite telemetry studies (e.g., Merrick *et al.*, 1994; Merrick and Loughlin, 1997). Observations and incidental take of sea lions (Loughlin and Nelson, 1986; Perez and Loughlin, 1991) in the vicinity of Seguam Pass, the southeastern Bering Sea, and Shelikof Strait provided a basis for establishment of those areas as critical habitat.

The POP database provides our best overall view of the foraging range or distribution of Steller sea lions in the Bering Sea and the western/central Gulf of Alaska (Figure 3.1-6). This database and the locations of sea lions taken incidentally in groundfish fisheries (1973 - 1988, Perez and Loughlin, 1991), indicate that sea lions disperse widely to forage throughout much of the Bering Sea and the GOA, at least as far out as the continental shelf break. Such broad dispersal may be essential to sea lion populations to take advantage of distant food resources and, as a consequence, limit intra-specific competition near rookeries and haulout sites. However, this database should be viewed with some caution. The sightings in the POP database were collected over a period of 4 decades and do not reflect any natural changes that may have occurred in sea lion foraging patterns during that period. Similarly, foraging range, as indicated by such sightings, would be expected to change over time due to the severe decline of the species in the last two decades. In addition,

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the database is biased as a reflection of overall foraging dispersion by the location of sighting effort. That is, a sighting at a particular location indicates sea lion presence at that site, but the lack of sightings at a site could mean that the site is not important for foraging or it could mean that there was insufficient sighting effort in that area. Also, it is not clear that each sighting represents a different animal, and it is possible that some sightings were of the same animal. Furthermore, the area may be important to sea lions during times of the year not covered intensively by sightings. Finally, the sighting database does not include information on the age and sex of the sighted animal.

Telemetry studies suggest that foraging distributions vary by individual, size or age, season, site, and reproductive status (Merrick and Loughlin, 1997). The foraging patterns of adult females differed during summer months when females were with pups versus winter periods when considerable individual variation was observed, but may be attributable to the lactation condition of the females. Trip duration for females ($n = 14$) in summer was approximately 18 - 25 hours. For five of those females that could be tracked, trip length averaged 10.5 miles (17 km) and they dove approximately 4.7 hours per day. For five females tracked in winter months, mean trip duration was 204 hours, mean trip length was 82.5 miles (133 km), and they dove 5.3 hours per day. The patterns exhibited by females in winter varied considerably, from which the investigators inferred that two of them may still have been supporting a pup. Those two females continued to make relatively shorter trips (mean of 32.9 miles [53 km] over 18 hours) and dove 8.1 hours per day, whereas the other three ranged further, dove 3.5 hours per day, and spent up to 24 days at sea. Five winter young-of-the-year exhibited foraging patterns intermediate between summer and winter females in trip distance (mean of 18.6 miles [30 km]), but shorter in duration (mean of 15 hours), and with less effort devoted to diving (mean of 1.9 hours per day). Estimated home ranges (mean \pm 1 SE) were 197 ± 38.4 miles² (319 ± 61.9 km²) for adult females in summer, $29,499 \pm 16,556.4$ miles² ($47,579 \pm 26,704$ km²) for adult females in winter, and $5,701.5 \pm 4,215.4$ miles² ($9,196 \pm 6,799$ km²) for winter young-of-the-year. The sea lions used in Merrick and Loughlin's (1997) study were from the GOA (Sugarloaf Island, Latax Rocks, Marmot Island, Long Island, Chirikof Island, Atkins Island, and Pinnacle Rock), and the BSAI region (Ugamak Island and Akun Island). This information is, therefore, directly pertinent to the action areas for both the GOA and BSAI fisheries, although it is perhaps most relevant to the GOA action area.

Overall, the available data suggest two types of foraging patterns: 1) foraging around rookeries and haulout sites that is crucial for adult females with pups, pups, and juveniles, and 2) foraging that may occur over much larger areas where these and other animals may range to find the optimal foraging conditions once they are no longer tied to rookeries and haulout sites for reproductive or survival purposes.

The sea lions in the Merrick and Loughlin (1997) study tended to make relatively shallow dives, with few dives recorded at greater than 820 feet (250 m) (Figure 3.1-7). Maximum depth recorded for each of the five summer adult females was in the range from 328 to 820 feet (100 to 250 m), and maximum depth for the five winter adult females was greater than 820 feet. The maximum depth measured for winter young-of-the-year was 236.2 feet (72 m). These results suggest that sea lions are generally shallow divers, but are capable of deeper dives (i.e., greater than 820 feet). The winter young-of-the-year sea lions were instrumented from November to March, when they were about 5 - 9 nine months old and may have still been nursing. At this age, they are just beginning to develop foraging skills, which may take years to learn. The diving depths and patterns exhibited by these young-of-the-year are not indicators of the foraging patterns of older juveniles (1 - 3-year-olds). For example, Swain and Calkins (1997) report dives of a 2-year-old male sea lion to 826.6 feet (252 m), and regular dives of this animal and a yearling female to 492 - 820 feet (150 m - 250 m). Clearly, if young-of-the-year are limited to relatively shallow depths, and older animals are capable of diving to much greater depths, then those younger animals are just beginning to develop the diving and foraging skills necessary to survive. The rate at which they develop those skills and begin to dive to greater depths

or take prey at greater depths is unknown, but probably occurs rapidly after weaning to take advantage of otherwise unavailable prey resources. The ADF&G is currently studying the ontogeny of dive behavior in young Steller sea lions.

A recent study analyzed data from 13 pup and 12 yearling Steller sea lions equipped with satellite dive recorders in the Gulf of Alaska/Aleutian Islands ($n = 18$), and Washington ($n = 7$) from 1994-2000 (Loughlin *et al.*, unpublished). A total of 1413 days of transmission ($\bar{x} = 56.5$ days, range 14.5-104.1 days) were received. They recorded 222,073 dives, which had a mean depth of 60.4 feet (18.4 m) (range of means 19.0 - 222.7 feet [5.8-67.9 m]). Alaskan pups dove briefer and shallower (mean depth $\bar{x} = 25.3$ feet [7.7 m], mean duration $\bar{x} = 0.8$ min, mean maximum depth $\bar{x} = 84.3$ feet [25.7 m], and maximum depth $\bar{X} = 826.6$ feet [252 m]) than Alaskan yearlings ($\bar{x} = 54.4$ feet [16.6 m], $\bar{x} = 1.1$ minutes, $\bar{x} = 63.4$ m, 944.6 feet [288 m], respectively), with Washington yearlings diving the longest and deepest ($\bar{x} = 129.2$ feet [39.4 m], $\bar{x} = 1.8$ minutes, $\bar{x} = 474.0$ feet [144.5 m], and 1,075.8 feet [328 m], respectively).

Loughlin *et al.*, unpublished) described three types of movements for these young sea lions, long-range trips (greater than 8 miles and greater than 20 hours), short-range trips (less than 8 miles and less than 20 hours), and transits to other sites. Transits began as early as 7 months of age, occurred more often after 9 months of age and ranged between 3.5 - 245 miles. Long-range trips started around 9 months of age and occurred most frequently at around the time of weaning while short-range trips happened almost daily (.9 trips/day, $n = 426$ trips).

3.1.1.6.3 Prey Species and Size

Steller Sea Lion Diet, Western Stock - Current ²

The most recent analysis of Steller sea lion diet compares trends in prey species consumption between summer and winter, when juveniles are first learning to forage on their own. (Sinclair and Zeppelin, submitted). Steller sea lion scats were collected (1990-1998) from 31 rookeries (May-September) and 31 haulout sites (December-April) across the U.S. range of the western stock resulting in a sample of 3,762 scats with identifiable prey remains. As is typical in marine mammal diet studies prey remains were identified to the lowest possible taxon using museum reference specimens. The relative importance of each prey species was based on their frequency of occurrence (FO).

Frequency of occurrence values combined across years, seasons, and sites depicted walleye pollock (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus monopterygius*) as the two dominant prey species, followed by Pacific salmon (Salmonidae) and Pacific cod (*Gadus macrocephalus*). Other primary prey species consistently occurring at frequencies of 5% or greater included arrowtooth flounder (*Atheresthes stomias*), Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), Irish lord (*Hemilepidotus sp.*), and cephalopods (squid and octopus). Species that occurred among the top three prey items on certain islands included: snailfish (Liparididae), rock greenling (*Hexagrammos lagocephalus*), kelp greenling (*Hexagrammos decagrammus*), sandfish (*Trichodon trichodon*), rock sole (*Lepidopsetta bilineata*), northern smoothtongue (*Leuroglossus schmidtii*), skate (Rajidae), and smelt (Osmeridae) (Figure 3.1-8).

²Discussion of current diet trends in the western stock of Steller sea lions is based on a recently submitted draft publication (Sinclair and Zeppelin, submitted) and should not be cited without permission from the authors.

Sites where the FO were most similar were identified using Principal Components and Agglomerative Hierarchical Cluster Analysis (Ward, 1963; Ramsey and Schafer, 1996) resulting in regions of diet similarity. These newly defined diet regions were used to compare regional and seasonal differences in prey. The diet divisions closely paralleled those defined as metapopulations based on patterns in population decline by York *et al.* (1996) suggesting that diet and decline are linked (Figure 3.1-9).

Chi-square analysis demonstrated significantly ($P = 0.01$) strong seasonal patterns in diet within each of the defined diet regions (island groupings as defined by cluster analysis). Pacific cod FO was significantly larger in winter in every region. Salmon FO was significantly lower during winter in the western Gulf of Alaska through the eastern Aleutian Islands, and higher in winter throughout the central and western Aleutian Islands. In the western Gulf, where arrowtooth flounder is most abundant in scats and well represented year-round, its FO was significantly lower in winter. Atka mackerel was significantly lower in the winter in the central and western Aleutians where it is the dominant prey species year-round. Forage fishes (herring and Pacific sand lance) are significantly different between seasons, however, there is no general trend among the regions. Walleye pollock is an important prey year-round in all regions up to the central Aleutian Islands where it is replaced by Atka mackerel. Likewise, cephalopod FO was not significantly different between seasons in any Region. Irish lord FO was generally higher in winter than in summer and though rarely occurring during summer and not included in Chi-square analysis, sandfish and snailfish have relatively high occurrences during the winter across all regions.

Diet diversity, calculated using Shannon's index of diversity (Ludwig and Reynolds, 1988), indicated that the Unimak Pass area as well as Sea Lion Rock (Amak Island) on the continental shelf just eastward of the pass encompassed the regions of highest prey diversity in this study. In the midst of precipitous population declines range wide among the western stock (Loughlin *et al.*, 1992), Amak Island was among 5 other rookeries identified by York *et al.* (1996) that demonstrated persistently stable or increasing population counts: Amak, Akun, Akutan, Chernabura, Clubbing, Ugamak. The York *et al.* (1996) temporal model for extinction of the western stock predicted that in the face of extinction of all other sites, these six would remain viable. All of these sites fall within Regions 2 and 3 as defined in this study, regions of highest diversity and greatest overlap in prey matrices between regions in this study (Figure 3.1-9). Implications of the importance of diversity in otariid diet (Merrick *et al.*, 1997; Sinclair *et al.*, 1994), though difficult to measure, should be further addressed, with special attention given to the dynamics of physical and bottom-up processes that influence nearshore habitat of rookery regions and ultimately, the population stability of Steller sea lions.

Based on the patterns in prey consumption presented in this (Sinclair and Zeppelin, submitted) and earlier studies (Fiscus and Baines, 1966; Pitcher, 1981; Calkins, 1998) Steller sea lions specialize feeding throughout the water column in the epipelagic (herring), demersal (arrowtooth flounder), and semi-demersal (pollock, Atka mackerel) zones. While the size of prey consumed undoubtedly varies with the age and sex of sea lion sampled, the remains of primary prey represented in this study are largely from adult fish (Zeppelin *et al.*, in prep). The seasonal and regional patterns in prey consumption by Steller sea lions presented in this study, along with known distributions of their primary prey, indicate that Steller sea lions target prey when they are densely schooled in spawning aggregation nearshore (over or near the continental shelf) or along oceanographic boundary zones. This is true in summer when collected scats are primarily from adult females, and in winter when scats are presumably from some increased proportion of juveniles and adult males as well as females.

The close parallel of these data (Sinclair and Zeppelin, submitted) with those of metapopulation patterns of decline (York *et al.*, 1996) suggests that diet and decline of Steller sea lions is linked; that diet diversity is

highest where population trends are most positive; and that regional diet patterns generally reflect regional foraging strategies learned at or near the natal rookery site on seasonally dense prey patches characteristic of that area. These data do not reflect Steller sea lion diet outside the range of the U.S. western stock. Goto and Shimazaki (1998) examined stomachs from 67 Steller sea lions killed by hunters off the coast of Hokkaido, Japan during 1994-1996. The most common prey was walleye pollock, but other common prey included Pacific cod, saffron cod, cephalopods, and flatfishes (Pleuronectidae).

Steller sea lion diet, western stock - historical

Prior to the 1990s, diet studies on Steller sea lions were based on the prey remains from stomachs of animals collected at sea or on rookery and haulout sites. Typically, sample sizes were small and singular publications reported on diet findings from various parts of the range of Steller sea lions, including the diet of animals collected (unknowingly) from both the eastern and western stock. The review of historical diet literature provided here regards only those findings from animals that were likely from the western stock - animals collected eastward of 144°. In other words, if authors reported results of their analyses of animals collected both in southeast Alaska and the western Aleutians, only the latter were reviewed here. Direct comparisons between historical and current studies must be viewed with some degree of caution due to these differences in methodologies. Nonetheless, indications of a shift in Steller diet since the mid-1970s are similar to those reported for other apex predators as well as findings of fisheries research surveys in the northern North Pacific Ocean and Bering Sea. That is, pollock have always been present in the system and in the diet of apex predators for which diet trend data is available (northern fur seals, murre, Steller sea lions), often among the top four prey items present. Whereas now, they are consistently the dominant, year-round, prey staple for these same predators.

In terms of the species of fish eaten by Steller sea lions, recent diet work (Sinclair and Zeppelin, submitted) compares most closely with studies conducted since the mid-1970s. In studies conducted along the range of the western stock between 1958 and 1969, pollock were completely absent from Steller diet (Mathisen *et al.*, 1962; Thorsteinson and Lensink, 1962; Tikhomirov, 1964; Fiscus and Baines, 1966). The high occurrence of pollock in Sinclair and Zeppelin (submitted) this study is most comparable to diet studies conducted since 1975 (Calkins, 1998; Frost and Lowry, 1986; Merrick *et al.*, 1997³; Pitcher, 1981) and possibly prior to the 1950s when Imler and Sarber (1947) reported pollock in 2 stomachs collected near Kodiak Island in 1945-1946. Sinclair and Zeppelin (submitted) also highlight the importance of Pacific cod in Steller diet during the winter months. Prior to this work, relatively few papers have focused on winter diet, so it is difficult to assess whether consumption of Pacific cod by Steller sea lions is a recent trend. Pacific cod was a top prey item in Calkins (1998) Bering Sea winter collections, and in stomachs that may have been collected in winter in the Gulf of Alaska 1973-1975 (Pitcher 1981). Overall, the most common prey items in studies prior to the mid-1970s included: capelin (*Mallotus villosus*), sand lance, cephalopods, herring, greenlings (Hexagrammidae), rockfishes, and smelts. Capelin, which were important in Steller diet through the 1970s (Fiscus and Baines, 1966; Pitcher, 1981) do not have an occurrence greater than 5% in recent studies. Salmon were present in early studies, but, not at the frequencies found across the western range during the summer. The occurrence of flatfish, especially Arrowtooth flounder, in the Gulf of Alaska is substantially higher now than any previous studies. Cephalopods were among the top prey items found in

³Merrick *et al.* 1997 was based on portions of the 1990-1993 dataset incorporated into Sinclair and Zeppelin (submitted).

Steller sea lion stomachs in many early studies (Mathisen *et al.*, 1962; Pitcher, 1981; Thorsteinson and Lensink, 1962), sometimes ranking as the most frequently occurring prey item (Fiscus and Baines, 1966). Cephalopod occurrence in Sinclair and Zeppelin (submitted) was primarily limited to the central and western Aleutian Islands and highest during the summer months, but never reached the high frequencies of the 1960s. The difference in cephalopod values between recent scat and historical stomach based diet studies may be due to differences in representation of cephalopod beaks in scats versus stomachs.

3.1.1.6.4 Prey Quality

An important consideration in evaluating effects of changing diets or prey abundance on Steller sea lions is the quality of the prey. Lipid content, and therefore energy density, varies greatly among Steller sea lion prey species, and within prey species depending upon life history stage, location and time of year (Stansby, 1976; Van Pelt *et al.*, 1997; Payne *et al.*, 1999; Anthony *et al.*, 2000). Atka mackerel and gadids are generally lower energy dense prey species (ranging within about 3 kJ/g - 6 kJ/g, though few data exist for Atka mackerel), while forage fish such as eulachon, herring, or capelin have generally higher energy contents (up to about 11 kJ/g). Because energy densities are seasonally variable, this is not an absolute relationship. For example, capelin and sandlance declined in lipid content, and therefore energy density, throughout the summer, from 6.7 kJ/g to 3.7 kJ/g and 6.5 kJ/g to 4.8 kJ/g respectively (Anthony *et al.*, 2000).

In addition to considerations of prey energy content, vitamins and other metabolites are essential for adequate nutrition. There is evidence from captivity that marine mammal diets entirely or largely comprised of clupeid (herring) and osmerid (smelt) induces thiamin deficiencies (Geraci 1981). This has not been diagnosed with certainty in otariids, though it was thought to be observed in California sea lions. The potential for fish-induced anemia in marine mammals was also highlighted by Geraci (1981) based on symptoms expressed in terrestrial mammals fed primarily gadid fish. This condition was found in mink fed thawed raw gadoid fish, but not fresh raw fish, and has not been directly observed in marine mammals. However, Thompson *et al.* (1997) and Fadely (1997) referenced this mechanism when circumstantially associating similar hematologic findings in free-ranging harbor seals with evidence for switching between clupeid and gadoid diets.

The ultimate net energy gain imparted to an animal from ingesting a particular prey item not only depends upon the energy content of the prey, but also on the costs associated with traveling to, finding, capturing, handling, and digesting the prey. It thus also depends on the prey item's individual size, total biomass, availability, behavior, degree of aggregation, temporal and spatial distribution, and so on. That is, the value of any particular prey type depends on the net gain to a sea lion from foraging on that prey, and net gain is a function of multiple factors of which lipid content is an important, but not the only, determinant.

3.1.1.6.5 Foraging - Integration and Synthesis

Foraging patterns of Steller sea lions are still far from being completely described. However, the available information suggests that:

- Steller sea lions are land-based predators but their attachment to land and foraging patterns/distribution varies considerably as a function of age, sex, site, season, and reproductive status, and as a function of prey availability and environmental conditions.

- Steller sea lions tend to be relatively shallow divers but are capable of (and apparently do) exploit deeper waters (e.g., to beyond the shelf break).
- Foraging sites relatively close to rookeries may be particularly important during the reproductive season when lactating females are limited by the nutritional requirements of their pups.
- Pups dependent upon mothers for nutrition tend not to disperse greatly and remain relatively nearshore conducting shallow dives.
- Yearlings that have reached nutritional independence greatly increase their foraging area, and begin deeper diving.
- Food availability may be extremely important during April - June, when pups are likely to be making a transition to nutritional independence, and the energy requirements of pregnant females are about double that of nonpregnant females.
- Dominant prey items vary with region and season, but pollock, Atka mackerel, Pacific cod and salmon are generally the most common or dominant prey.
- Steller sea lions consume a variety of demersal, semi-demersal, and pelagic prey, indicating a potentially broad spectrum of foraging styles.
- Diet diversity may influence status and growth of Steller sea lion populations.
- The life history and spatial/temporal distribution of important prey species are likely important determinants of sea lion foraging success
- The broad distribution of sea lions sighted in the POP database indicates that sea lions also forage at sites distant from rookeries and haulout sites.
- The availability of prey at these sites may be crucial in that they allow sea lions to take advantage of distant food sources, thereby mitigating the potential for intraspecific competition for prey in the vicinity of rookeries and haulout sites.
- The question of whether competition exists between the Steller sea lion and BSAI or GOA groundfish fisheries is a question of sea lion foraging success. For a foraging sea lion, the net gain in energy and nutrients is determined, in part, by the availability of prey or preypatches it encounters within its foraging distribution. Competition occurs if the fisheries reduce the availability of prey to the extent that sea lion condition, growth, reproduction, or survival are diminished, and population recovery is impeded.

3.1.1.7 Physiology and Nutrition

Fundamental to an evaluation of the effects of commercial fisheries on Steller sea lions is an understanding of the physiological adaptations and nutritional requirements that underlie the sea lion's role in the Bering Sea and Gulf of Alaska ecosystems. Steller sea lions spend time on land at rookeries and haulout sites for reproduction, lactation, molting and resting, and undertake foraging trips to sea. The relative time spent at

sea depends upon age and size, season, reproductive status, and the availability of forage (Boyd, 1995; Boyd, 1996). Trips to sea may be made for a variety of reasons, for foraging but also for seasonal or age-specific movements along the coast. While foraging, swimming and diving behavior are controlled by a compromise between the necessity to breathe at the surface and to submerge to seek and consume prey. In addition to the abundance and distribution of prey, the time a sea lion spends submerged will depend upon physiological adaptations for maximizing time underwater. This will be a result of the how fast oxygen stores are utilized (that is, metabolic rate), and how much oxygen is stored in the body, and the conflicting demands of diving and exercise (Castellini, 1991; Boyd, 1997). Pinnipeds exhibit many physiological strategies to increase dive duration (Boyd and Croxall, 1996; Boyd, 1997).

During a dive, approximately 47% of a sea lions oxygen stores are in blood, with 35% in muscle and the remainder in the lungs (Kooyman, 1985). There is a considerable developmental component until the oxygen storage ability of an otariid is fully matured (Horning and Trillmich, 1997), because of increases in blood volume, muscle myoglobin and body mass. Likewise, juveniles operate at metabolically higher rates than adults (Lavigne *et al.*, 1986; Costa, 1993). Thus, younger sea lions do not have the same capacity to stay submerged (and hence dive to as great of depths) as adults, which consequently affects their ability to acquire prey and thus choice of foraging strategies.

Sea lions have a streamlined shape that minimizes the cost of transport while swimming (Feldkamp, 1987; Stelle *et al.*, 2000). Laboratory measurements of swim speed and drag in 3 year old Steller sea lions showed that they preferred to swim at a mean velocity of 3.41 m s^{-1} ($2.9\text{-}3.4 \text{ m s}^{-1}$), equivalent to 1.46 body lengths per second (Stelle *et al.*, 2000), a speed found to be the minimum cost of transport for California sea lions (Feldkamp, 1987). Williams *et al.* (1991) found that the average ventilation time did not change with swim speed in California sea lions. That is, time spent submerged did not change as swim speeds increased to 4.37 yd s^{-1} (4 m s^{-1}). Because of anatomical adaptations, sea lions appear to require shorter times for lung tidal volume exchange than do seals (Williams *et al.*, 1991). Skeletal muscles of pinnipeds (and sea lions) are adapted for aerobic metabolism of lipids during hypoxic conditions of diving and exercise (Kanatous *et al.*, 1999). Lipid stores in swimming muscle were sufficient to meet the resting muscle metabolism for 17 hours in Steller sea lions (Kanatous *et al.*, 1999).

Food Intake Requirements

Kastelein *et al.* (1990) measured the daily food intake rate of 10 captive Steller sea lions for a 15 year period. The sea lions were fed 3 - 6 times per day on a mixture that averaged 22% mackerel, 40% herring, 10% sprat, 14% whiting (a gadid), and 14% squid based on weight. They found large seasonal variation in daily intake rates, with a particularly strong depression of consumption during summer months in males between 8-15 years old. Seasonality of intake was presumably related to hormonal influences, changes in energy requirements due to reproduction, and seasonal temperature changes. Much of these effects could be influenced or transduced by changes in sea lion body mass or composition, which they could not measure.

To estimate the amount of food required by Steller sea lions in the wild, more detailed measurements of metabolic rates and food intake requirements have been measured in captivity. The amount of energy derived from food can be described by following the bioenergetic scheme which details the efficiencies and costs of metabolizing food at various steps in the digestive process (Lavigne *et al.*, 1982). Proportions of proteins, lipids, or undigestible matter in a prey item affect its ability to be absorbed and digested in the body. Energy available in the prey is lost throughout the digestive process before it becomes available for activity, growth or reproduction by the sea lion, and varies depending upon the relative amounts of protein and lipid or energy

density in the diet item (Rosen and Trites, 2000a; Rosen and Trites, 2000b). Laboratory measurements of nutritional requirements seek to control multiple sources of variation that affect the amount of energy derived from prey. Then, if the costs of various activities are also determined, it is possible to model the nutritional requirements of sea lions in the wild. This provides a basis to determine the effects of consuming prey items with varying energy content.

Assimilation (dry-matter) efficiencies of northern fur seals, California sea lions, and Steller sea lions fed herring range from 86.9% to 93% (Miller, 1978; Fadely *et al.*, 1990; Fadely *et al.*, 1994; Rosen *et al.*, 2000; Rosen and Trites, 2000a), and for pollock between 81.3% - 90% (Miller, 1978; Fadely *et al.*, 1994; Rosen and Trites, 2000a). In terrestrial mammals, larger meal sizes or increased feeding frequency may decrease assimilation efficiencies (Golley *et al.*, 1965), but while these effects may have been observed in ringed seals (Parsons, 1977), harp seals (Keiver *et al.*, 1984) and northern fur seals (Fadely *et al.*, 1990), it was not observed in Steller sea lions (Rosen *et al.*, 2000) or in other studies of harp, ringed or grey seals (Ronald *et al.*, 1984; Lawson *et al.*, 1997a; Lawson *et al.*, 1997b). Because fish have relatively small indigestible fractions, there is a linear relationship between digestive efficiency and assimilation efficiency, and digestive efficiencies are likewise high (Rosen *et al.*, 2000) but not equivalent because of prey composition. When compared to other pinnipeds, assimilative and digestive efficiencies of Steller sea lions are comparable (Rosen and Trites, 2000a).

However, the cost of consuming low-energy prey items may be greater than expected purely based on differences in prey energy content. Captive feeding trials using six Steller sea lions ranging in age between 0.9 and 4.5 years old were fed herring or pollock diets over periods of 7 - 24 days to measure differences in metabolism and digestive efficiency (Rosen and Trites, 1997; Rosen and Trites, 1999; Rosen and Trites, 2000a; Rosen and Trites, 2000b; Rosen *et al.*, 2000). Based on the gross energy content differences between the two diets, the captive sea lions were expected to consume about 35% - 65% more pollock than herring. However, results suggested that because of additional costs of digesting pollock and a slightly lower digestive efficiency relative to a herring diet, the sea lions would have had to consume about 35% - 80% more pollock than herring (Rosen and Trites, 2000b). The sea lions in that study were unable or unwilling to consume the additional amounts of pollock, and hence lost body mass in spite of also reducing resting metabolic rates (Rosen and Trites, 1999).

A Steller Sea Lion Recovery Team review of captive feeding studies performed to date suggested that these studies may not be generally representative of field situations (Didier 1999), a point that has also been highlighted by researchers conducting the studies (Fadely *et al.*, 1994; Rosen and Trites, 2000b). They cited the short duration, often less than two weeks, which may have been inadequate to trigger cues utilized by sea lions to adjust intake in response to dietary changes. Likewise, these studies did not directly measure changes in activity or body condition, which also affect food intake rates. As a goal of the captive feeding studies was specifically to detect differences in metabolism related to prey composition, sea lions were fed single-species diets to maximize potential treatment effects, and as such, these studies present important data regarding metabolic adjustments that can be made in response to diets of differing quality. However, the diet of free-ranging sea lions does not consist exclusively of single prey items, prey vary in energy density throughout the year, and it is also unknown how availability of prey may affect total intake (Rosen and Trites, 2000b).

A subsequent set of captive feeding studies are being conducted to address many of these concerns by performing feeding trials throughout the year, and by using mixed diets based on known diet compositions of free-ranging sea lions (Castellini, 2001). Using mixed diets based on pre-decline, decline, and southeast Alaska prey frequencies of occurrence in sea lion diets, preliminary results indicate that in some seasons,

body mass is defended regardless of diet, and sea lions adjust volume consumed; two sea lions showed relatively stable body composition regardless of diet, a third changed composition; and, all sea lions had maintained excellent health and condition regardless of diet. Thus, while a monospecific diet of low-fat prey may be nutritionally limiting to sea lions under certain conditions, results from feeding trials performed over longer periods with diet mixtures reflective of wild sea lions have the potential to refine our understanding of free-ranging dietary needs of sea lions. And though captive feeding studies can describe the metabolism of prey once ingested, they do not include components of foraging efficiency, or the cost to the sea lion of acquiring a certain prey type.

With estimates of food intake requirements, population size and age structure, and of activity, it is possible to generate estimates of food intake requirements for the entire population of Steller sea lions. Perez and McAllister (1993) estimated annual food consumption by the Steller sea lion population in the eastern Bering Sea as 18.5×10^4 mt, of which 14.1×10^4 mt (76 percent) was fish. Of the total annual fish consumption, commercial groundfish comprised 69 percent. Winship (2000) built a Steller sea lion bioenergetic model incorporating variability in estimates of sea lion growth, metabolism, activity, and diet to produce more robust estimates of population food intake requirements. Estimates of annual prey biomass consumption varied seasonally, and by up to 12% among regions of Alaska due to differences in population size and diet composition (Winship, 2000). The southeast Alaska population consumed the greatest biomass annually, while the central Aleutian Islands population consumed the least. Similar amounts of gadids were consumed annually by the Gulf of Alaska (7.64×10^4 mt) and southeast Alaska populations (7.29×10^4 mt). The second largest single species consumption was of Atka mackerel by the central Aleutian Islands population (4.87×10^4 mt). Winship (2000) estimated that the total annual consumption of pollock by all sea lions was 6% of the total estimated pollock biomass attributed to natural mortality, and 19% of the total biomass removed by commercial fisheries. Steller sea lion predation accounted for a greater proportion (83%) of the estimated biomass of Atka mackerel annual natural mortality. However, this type of analysis does not consider spatial, temporal or local availability of prey to sea lions, particularly on scales relevant to foraging sea lions (Winship, 2000).

Physiology and Foraging - Integration

Field measurements of metabolic rate or energy consumption show that otariids generally operate at 3-6 times their basal metabolic rate while traveling and foraging (Costa *et al.*, 1989; Arnould *et al.*, 1996; and see Winship, 2000). This is higher than measurements for phocids, and reflects a high energy strategy for foraging. In general, otariids have adopted an “energy maximizer” type foraging strategy, which is characterized by high energy turnover. That is, sea lions expend comparatively (to phocids) high levels of energy to acquire relatively high levels of energy. This strategy is advantageous in highly productive ecosystems with concentrated and predictable prey (Costa, 1993).

Otariids can make adjustments to foraging strategies on many behavioral and metabolic scales. Changes in foraging trip duration and in time at a prey patch have been observed in response to prey availability (Boyd, 1996; Boyd, 1999; Andrews, 2001). Responses by sea lions will vary depending upon life history status, for example, whether an adult female is lactating or not, or whether a mother-pup pair is at a rookery (central place foraging), or foraging from multiple haulout sites (multiple central place foraging). This change in strategy is likely related to costs of lactation, when at some point it becomes more advantageous energetically for the female to move away from the rookery with the pup, though it is not yet weaned, to allow exploitation of prey with a higher rate of energy return (Boyd, 1998), either because of prey proximity, quality, or abundance at sites other than near the rookery.

Individual foraging strategies will vary depending upon prey location and quality. If prey are not shallow, travel costs increase to access the prey patch. At some combination of prey size, quality, number, catchability and depth, it will become suboptimal for a sea lion to forage on a given prey type (Boyd, 1997). This type of foraging decision was recently directly observed by Thomas and Thorne (2001), where sea lions in Prince William Sound were observed feeding on surface schooling herring, rather than diving to a deeper, though more concentrated, school of pollock.

3.1.1.8 Anthropogenic Sources of Mortality

Anthropogenic, or human-caused, sources of mortality can occur incidental to other actions, or through directed taking. Examples are mortalities that occur incidental to commercial fishing, through entanglement in derelict fishing gear or other debris, directly through subsistence harvests, or directly by illegal shooting or other action.

A primary source of data for the rate of mortalities that occur incidental to commercial groundfish fishing is from the North Pacific Groundfish Observer Program database. Based on recent observer data, minimum estimates of mean annual mortality for the BSAI groundfish trawl fishery are 7.0 (CV = 0.21) sea lions per year for the past 5 years, 1.2 (CV = 0.6) sea lions annually for the GOA groundfish trawl fisheries, and 0.8 (CV = 1.0) for the GOA groundfish longline fishery (Angliss *et al.*, 2001). Resultant ranges of observer coverage relative to fishing effort was 53% - 74% for BSAI groundfish trawl, 33% - 55% for GOA groundfish trawl, and 8% - 21% for GOA groundfish longline fisheries (Angliss *et al.*, 2001). There appears to have been a slight decline in estimated incidental take rates throughout the 1990s. A closer examination shows no apparent 'hot spots' of incidental catch (Figure 3.1-10), nor an apparent relationship between mortality and magnitude of catch. Because of the size class requirements for observer coverage, if vessels with limited or no coverage operate in ways different than the larger vessels, either in technique or area, then these mortality estimates could potentially be biased.

Steller sea lions are incidentally taken by commercial fisheries other than groundfish fisheries, including some nearshore salmon drift or set gillnet fisheries and halibut longline fisheries. An estimated minimum mean annual mortality rate from the past five years of data for all commercial fisheries taking Steller sea lions from the western stock is 28.3 (CV = 0.64) sea lions per year (Angliss *et al.*, 2001). However, many fisheries known to interact with Steller sea lions have not been observed, and thus this should be considered a minimum estimate.

Entanglement of Steller sea lions in derelict fishing gear or other materials seems to occur at frequencies that do not have significant effects upon the population. From a sample of rookeries and haulout sites in the Aleutian Islands, of 15,957 adults observed, Loughlin *et al.* (1986) found only 11 (0.07%) entangled in marine debris, some of which was derelict fishing gear. Observations of sea lions at Marmot Island for several months during the same year observed 2 of 2,200 adults (0.09%) entangled in marine debris. During 1993-97, only one fishery-related stranding was reported from the range of the western stock, a sea lion observed in August 1997 with troll gear in its mouth and down its throat (Angliss *et al.*, 2001). Entanglement of sea lions in derelict fishing gear or other marine debris does not appear to represent a significant threat to the population.

Steller sea lions are primarily utilized for subsistence purposes in communities within the range of the western stock. Pinniped harvests in southeast Alaska tend to be dominated by harbor seal rather than Steller sea lions, and essentially all of the harvest is from the western stock. Of these, most are harvested in the

Pribilof Islands. Estimates of the total number of sea lions taken (harvested plus struck and lost) declined over the six year period of 1992 - 1998 from 549 to 171 per year (Angliss *et al.*, 2001), with an overall mean annual take of 329 sea lions for the entire period.

Harvest levels typically have been lowest during June - August, peaking during September - November and declining through May, but this seasonality has been less pronounced since 1996 with declining harvest rates (Wolfe and Mishler, 1997). The proportion of the harvest comprised of female sea lions has been relatively low. For 1996 - 1998, adult females comprised 14.2%, 9.2%, and 6.9% of the total harvest, while juvenile females accounted for 5.8%, 6.9% and 3.0% (Wolfe and Mishler, 1997; Wolfe and Hutchinson-Scarborough, 1999). Takahashi and Wada (1998) used a modified Leslie matrix model to assess the possible effect of hunting Steller sea lions in Japanese waters and concluded that hunting near Hokkaido to reduce damage to local fisheries likely depleted the sea lion population in the Kuril Islands.

Illegal shooting occurs, but the frequency of occurrence is difficult to estimate. NMFS successfully prosecuted two cases of illegal shooting of sea lions in the Kodiak area in 1998, and two cases in southeast Alaska between 1995 - 1999 (Angliss *et al.*, 2001).

Based on a published life table and the current rate of decline, Loughlin and York (2001) estimate the total number of mortalities of non-pup Steller sea lions in 2000 was about 6,425 animals; of those, 4,710 (73%) were mortalities that would have occurred if the population were stable, and 1,715 (27%) were additional mortalities that fueled the decline. They tabulated the levels of reported anthropogenic sources of mortality (subsistence, incidental take in fisheries, and research), guessed at another (illegal shooting), then approximated levels of predation (killer whales and sharks). They attempted to partition the various sources of "additional" mortalities as anthropogenic and as additional mortality including some predation. Loughlin and York (2001) classified 438 anthropogenic mortalities and 779 anthropogenic plus some predation mortalities as "mortality above replacement;" this accounted for 25% and 45% of the estimated total level of "mortality above replacement." The remaining mortality (75% and 55%, respectively) was not attributed to a specific cause and may be the result of nutritional stress.

3.1.1.9 Natural Predators

A brief review of predation on Steller sea lions by killer whales and sharks was presented in the 2000 BSAI/GOA groundfish BIOP (NMFS, 2000). Based on surveys of researchers, fishers, tour boat operators and others, more lethal interactions may occur in the Aleutian Islands compared to other parts of Alaska (Barrett-Lennard *et al.*, 1995). In a study dedicated to tracking killer whales in Prince William Sound during 1984 - 1996, 31 documented marine mammal kills by transient killer whales none were of Steller sea lions (Saulitas *et al.*, 2000). However, nearly 33 (14/43) observed harassments of Steller sea lions by PWS or GOA transient killer whales were observed. Observations were conducted during summer months, and the availability of juvenile sea lions to killer whales may be higher in this area during spring months, when sea lions arrive seeking herring. Based in part on these observations, and on stomach contents of six stranded killer whales, sea lions were estimated to comprise 5% - 20% of killer whale diet (Matkin *et al.*, 2001). Expanding this to account for daily killer whale metabolic needs, average size and caloric content of sea lions consumed, and a population estimate of killer whales, a range of the percent of sea lion mortalities attributable to killer whales was estimated to be 6% - 77%, with a best estimate of 27% (Matkin *et al.*, 2001). The results of this exercise highlighted the need for improved data on killer whale population size and proportion of sea lions in their diet, and suggests that killer whale predation may be a factor in current decline and lack of recovery of sea lions. (Estes *et al.*, 1998; Matkin *et al.*, 2001).

Attacks by great white sharks have been documented on sea lions at the southern end of their range in California (Ainley *et al.*, 1985). Though Alaska waters lie mostly north of the theorized normal range of white sharks, sleeper sharks (*Somniosus pacificus*) range throughout the Gulf of Alaska and Bering Sea, and small marine mammals have been documented in stomach contents (Yang and Page, 1999). One such occurrence was the discovery of harbor seal remains from one shark taken in Alaska (Bright, 1959), though whether this seal was predated or scavenged is unclear. There have also been recent reports of sleeper sharks collected in Alaska containing cetacean and harbor seal remains (Hulbert *et al.*, 2001). No remains of Steller sea lions were found in 13 sleeper shark stomachs collected in the Gulf of Alaska between June and August 1996 in areas near active sea lion rookeries and haulout sites (Yang and Page, 1999). Though this is a small sample size, the stomach contents indicated primarily benthic feeding, despite the proximity and local abundance of sea lion pups (Yang and Page, 1999). Pinniped residues were found in the stomach of 1 sleeper shark among 148 sampled from the Bering Sea in 1997 (Orlov, 1999).

3.1.1.10 Disease and Contaminants

As with any wild mammal population, a multitude of infectious (viral, bacterial, parasitic, or mycotic) or toxicological (heavy metal, organochlorine) diseases may afflict Steller sea lions. Many anatomical and clinical studies have been performed to determine disease prevalence, with an ultimate goal of determining incidence, interactions with environment, and what role disease may play in the population decline or as an impediment to recovery.

Infectious

Many diseases common to otariids in general and sea lions specifically can cause reproductive failure or death, and have thus been considered relative to their role in the population decline (NMFS, 1995). Among those potentially pathogenic that have tested positive for exposure in some sea lions are calicivirus (San Miguel sea lion virus; Barlough *et al.*, 1987), *Listeria* sp. (Spraker and Bradley, 1996), *Edwardsiella tarda* (Spraker and Bradley, 1996), *Bordetella bronchiseptica* (Spraker and Bradley, 1996), canine distemper virus, phocine distemper virus, phocid herpesvirus 1, *Salmonella* sp. (Spraker and Bradley, 1996), *Toxoplasma gondii*, and chlamidia (Sheffield and Zarnke, 1997). Prevalence or isolation of pathogens occurs throughout the range, with no immediate temporal/spatial pattern detectable due largely to small or infrequent sampling (Sheffield and Zarnke, 1997; NMFS, 1995). No exposure to influenza A or *Brucella* spp. was detected (Sheffield and Zarnke, 1997).

Parasitic

Calkins *et al.* (1994) reported finding numerous lesions in adult and juvenile sea lions necropsied during the *Exxon Valdez* oil spill. Gross lesions caused by parasites were found in the nasal cavity, stomach, and intestine, and were unrelated to hydrocarbon exposure (Calkins *et al.*, 1994).

Nasal mites infect sea lions in Alaska (Fay and Furman, 1982) and Russia (Konishi and Shimazaki, 1998) by at least two years of age, though nasal mites and sea lions have apparently evolved into a relatively neutral, or benign, relationship (Konishi and Shimazaki, 1998).

Contaminants

Organic and inorganic chemicals from pesticides and industrial applications that accumulate in food webs and are hazardous to wildlife include persistent organic pollutants (such as DDT, PCBs, chlordane, hexachlorocyclohexane, dioxin), heavy metals (lead, cadmium, mercury), radioactive elements or compounds, and petroleum hydrocarbons. Contaminants can be transported to Alaska via atmospheric or oceanic currents, or can be found in localized point sources such as abandoned military installations, industrial complexes, mining sites, land or sea dumps, and from discharges or spills (AMAP, 1997). Contamination of wildlife can result from inhalation, absorption through skin, direct ingestion, or by consumption of contaminated prey (Marine Mammal Commission, 1999). Changes in diets or ecosystem trophic webs can thus affect the contaminant burden of top predators (Marine Mammal Commission, 1999). Toxic effects of contaminants in wildlife and marine mammals have been associated with reproductive failures (Helle *et al.*, 1976; Reijnders, 1986), population declines (Martineau, 1987), carcinomas (Gulland *et al.*, 1997), and immune suppression (deSwart *et al.*, 1995; Ross *et al.*, 1996).

Few analyses have been published on heavy metal contamination in Steller sea lions. Evidence of transitory metals accumulation in southeast Alaska sea lions was found by Castellini and Cherian (1999). They found that circulating zinc (Zn) and metallothionein (a chelating compound) were increased in southeast Alaska sea lion pups during the early 1990s, and returned to values comparable to Aleutian Island pups by 1997. Zinc, copper, and metallothionein levels were comparable between pups sampled from the western stock and Forrester (Lowrie) Island (eastern stock), and lower than captive sea lions (Castellini and Cherian, 1999). Hepatic metal concentrations in Steller sea lions have generally been much lower than found in northern fur seals (Noda *et al.*, 1995). Vanadium concentrations in Steller sea lion livers ranged between 0.023-0.43 µg/g of wet weight, and positively correlated with levels of selenium, silver, and mercury (Saeki *et al.*, 1999).

No toxicological studies have been performed on otariids to determine clinical ramifications of increasing contaminant burdens. However, Organochlorines have been associated with levels of health concern in other animals. Mink kit survival was compromised at approximately 8,000 ng/g lipid weight (AMAP, 1997), immunosuppression in harbor seals was detected at average concentrations of 16,488 ± 1023 ng/g lipid weight, and premature parturition in California sea lions was observed at burdens of 134,000 ng/g lipid weight (DeLong *et al.*, 1973).

Lee *et al.* (1996) examined Steller sea lion blubber and liver samples from the Bering Sea and Gulf of Alaska and found that blubber PCBs ranged 5,700-41,000 ng/g lipid in males, and 570-16,000 ng/g lipid in females. PCB concentration in males was orders of magnitude higher than other Arctic and Alaskan pinnipeds. DDTs in levels in males ranged from 2.8 to 17 ng/g lipid and in females from 0.19 to 6.5 ng/g lipid. For males and females aged 6 and 8 years of age, DDE levels were 5.4 and 1.8 µg/g lipid wt, respectively. Females were found to decrease the contaminant burden throughout life, relative to adult males, by dumping contaminants through lactation. Varanasi *et al.* (1992) obtained sea lions samples from the Bering Sea, Barren Islands, Prince William Sound, and St. George Island (Pribilof Islands) and found organochlorine levels in the blubber at 23000 +/- 37000 ng/g, wet weight. There was large variance because of the large range of 1,800-110,000 ng/g. The high level at 110,000 ng/g was from a 1-2 year old male from the Bering Sea.⁴ Finally, the NMFS Northwest Center examined blubber samples from 24 Steller sea lions from southeast Alaska and report PCB levels of 630-9900 ng/g wet weight and DDT levels of 400-8200 ng/g wet weight, respectively

⁴Gina Ylitalo, Northwest Fisheries Science Center, NMFS, 2725 Montlake Blvd, Seattle, WA 98112.

(NMFS, unpublished)⁵. These studies indicate burdens are present in Steller sea lions that could be sufficient to produce health effects.

Concerns exist that the toxicity of contaminants may increase within an individual in negative energy balance, or nutritional limitation, as lipophilic contaminants such as PCBs are released as blubber stores are metabolized. While levels of circulating organochlorines did increase in the blood of harbor seals with high body burdens of organochlorines fasting for 15 days, immunological responses remained within normal ranges suggesting short-term fasting did not add an additional threat (De Swart *et al.*, 1995). Based on endocrine responses, however, seals with high levels of contaminants were likely to be less likely to adequately respond to stressful situations (De Swart *et al.*, 1995).

Sea lions exposed to oil spills may become contaminated with polycyclic aromatic hydrocarbons (PAHs) through inhalation, dermal contact and absorption, direct ingestion, or by ingestion of contaminated prey (reviewed in Albers and Loughlin, in press)). After the *Exxon Valdez* oil spill in March 1989, Calkins *et al.* (1994) recovered 12 sea lion carcasses from the beaches of Prince William Sound, and collected an additional 16 sea lions from haulout sites in the vicinity of PWS and the Kenai coast. The highest levels of PAHs were in sea lions found dead following the oil spill. Sea lions collected seven months after *Exxon Valdez* oil spill of 1989 in Prince William Sound had levels of PAH metabolites in the bile consistent with exposure and metabolism of PAH compounds (Calkins *et al.*, 1994). However, since lesions associated with hydrocarbon contamination were not found in histological exams of any sea lion, there was no evidence of oil toxicity damage (Calkins *et al.*, 1994).

Disease has not been considered to have played a significant role in the overall decline of the western stock of Steller sea lions (NMFS, 1995), but it is inconclusive to what extent it played as a contributory factor, and to what extent disease may be operating as a limitation to recovery. In declining populations, decreased genetic diversity and synergistic effects from chemical contaminant toxicity can act to compound factors that lead to reduced fitness (Bickham *et al.*, 2000).

Field Studies of Health and Condition

Several field studies have been conducted to assess health and condition of Steller sea lions utilizing hematological and morphometric indices of condition (see Donnelly and Trites, 2000 for a review). In general, health assessments based on blood profiles represent physiological responses to relatively recent effects, and thus are most useful for addressing questions about current health status. A limitation of assessing individual health based on a single sample is that without additional observations or sample gathering, it is difficult to generate a definitive diagnosis of a disease state should the indices indicate an abnormality. However, when multiple individuals are combined it may be possible to generate a picture of health status at a population level, a method commonly applied in domestic and wildlife medicine (Seal *et al.*, 1978; Franzmann, 1985), and has been applied to Steller sea lions (Bishop and Morado, 1995; Castellini *et al.*, 1993; Rea *et al.*, 1998). However, the utility of this type of analysis is highly dependent upon the type and scope of factors operating on the population, and on the sensitivity of the measured variables to those factors.

⁵D. DeMaster, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

A key to blood chemistry profiling is that metabolites present in the blood can be directly related to nutritional status as well as many other disease states, and can thus present a snapshot of health for animals sampled from a haulout or rookery. Blood chemistry profiles have in general not detected significant health issues for newborn to 1 month old Steller sea lion pups throughout their range in Alaska during the 1990s (Castellini *et al.*, 1993; Bishop and Morado, 1995; Rea *et al.*, 1998). Rea *et al.* (1998) did find metabolites in pups from southeast Alaska indicative of longer fasting periods than pups from the Aleutian Islands or Gulf of Alaska. This was consistent with longer periods between suckling associated with longer maternal foraging trips (Brandon *et al.*, 1996). However, levels of plasma haptoglobin, an acute phase reaction protein that increases in response to infection, inflammation, trauma and environmental stress, were found to be significantly elevated in pups and adults during 1992-1994 from the Aleutian Islands and Gulf of Alaska compared to those in southeast Alaska (Zenteno-Savin *et al.* 1997). This could indicate that some stressors were operating on populations in the areas of decline differently than on the area of stability.

Comparisons of growth measurements, such as mass or length at age, are more reflective of longer term conditions experienced by an animal. Steller sea lions sampled in the 1980s weighed less and were shorter for age than sea lions sampled during the 1970s (Calkins *et al.*, 1998), and were less massive than expected based on length-girth relationships (Castellini and Calkins, 1993). These differences were most notable among animals less than 10 years old (Calkins and Goodwin, 1988), and may have been declining since the 1960s (Calkins *et al.*, 1998). These changes are consistent with nutritional limitation. Recent comparisons of body size across regions of decline and stability do not recapitulate the long-term trend, however. There is evidence for larger pup sizes in areas of decline (Rea, 1995; Merrick *et al.*, 1995; Adams, 2000; Fadely and Loughlin, 2001), arising from differential growth rates (Brandon and Davis, 1999). Adult females with pups were not different in size between the regions of stability and decline (Davis *et al.*, 1996), though this sample of unknown age females may not be representative of the populations as a whole.

3.1.1.11 Natural Competitors

Steller sea lions forage on a variety of marine prey that are also consumed by other marine mammals (e.g., northern fur seals, harbor seals, humpback whales), marine birds (e.g., murre and kittiwakes), and marine fishes (e.g., pollock, arrowtooth flounder). To some extent, these potential competitors may partition the prey resource so that little direct competition occurs. For example, harbor seals and northern fur seals may consume smaller pollock than Steller sea lions (Fritz *et al.* 1995). Competition may still occur if the consumption of smaller pollock limits the eventual biomass of larger pollock for sea lions, but the connection would be difficult to demonstrate. Such competition may occur only seasonally if, for example, fur seals migrate out of the area of competition in the winter and spring months. Similarly, competition may occur only locally if prey availability or prey selection varies geographically for either potential competitor. Finally, competition between sea lions and other predators may be restricted to certain age classes, because diet may change with age or size.

3.1.1.12 Influence of environmental and climatic change on Steller sea lions

From 1940-1941 an intense Aleutian Low was observed over the BSAI, and GOA, this was followed from December 1976 to May 1977 with an even more intense Aleutian Low. During this latter period, most of the North Pacific Ocean was dominated by this low pressure system which signaled a change in the climatic regime of the BSAI, and GOA (NRC, 1996). The system shifted from a “cold” regime to a “warm” regime that persisted for several years. Since 1983, the GOA and Bering Sea have undergone different temperature changes. Sea surface temperatures in the GOA were generally above normal and those in the Bering Sea

were below normal. The temperature differences between the two bodies of water have jumped from about 1.1° C to about 1.9° C. Recent evidence now indicates that another regime shift occurred in the North Pacific in 1989 (NRC, 1996).

Most scientists agree that the 1976/77 regime shift dramatically changed environmental conditions in the BSAI and GOA (Benson and Trites, 2000). However, there is considerable disagreement on how and to what degree these environmental factors may have affected both fish and marine mammal populations. Productivity of the Bering Sea was high from 1947 to 1976, reached a peak in 1966, and declined from 1966 to 1997. Some authors suggest that the regime shift changed the composition of the fish community and reduced the overall biomass of fish by about 50 percent (Merrick *et al.*, 1995; Piatt and Anderson, 1996). Other authors suggest that the regime shift favored some species over others, in part because of a few years of very large recruitment and overall increased biomass (Beamish, 1993; Hollowed and Wooster, 1995; Wyllie-Echeverria and Wooster, 1998).

It is reasonable to conclude that the regime shift created environmental conditions that produced very large year classes of gadids (i.e. pollock and Pacific cod). However, because of the historically high catches of gadids before the regime shift occurred, it is not likely that the regime shift favored gadids in a way which would allow them to out compete other fish species and dominate the ecosystem, although the absolute level of biomass is not well known.

Many competing factors have contributed to the ecosystem in which Steller sea lions now depend Pauly *et al.*, 1998). However, the important question is whether the diet of Steller sea lions was adversely affected by the regime shift. Specifically, the question has been raised as to whether the increase in pollock abundance is now contributing to the decline of Steller sea lions. From the information available, it seems reasonable to conclude that gadids (i.e., pollock and Pacific cod) were abundant before the regime shift, and that sea lions relied upon them for food before the decline. Therefore, it is unlikely that a change in the structure of the ecosystem, resulting in a dominance of gadids is the sole cause of the current decline.

Shima *et al.* (2000), looked at the GOA and three other ecosystems which contained pinniped populations, similar commercial harvest histories, environmental oscillations, and commercial fishing activity. Of the four ecosystems only the GOA pinniped population (Steller sea lions) were decreasing in abundance. They hypothesized that the larger size and restricted foraging habitat of Steller sea lions, especially for juveniles that forage mostly in the upper water column close to land, may make them more vulnerable than other pinnipeds to changes in prey availability. They further reasoned that because of the behavior of juveniles and nursing females, the entire biomass of fish in the GOA might not be available to them. This would make them much more susceptible to spatial and temporal changes in prey, especially during the critical winter time period (Shima *et al.*, 2000).

Figure 3.1-1 Steller Sea Lion western stock population trends, 1976-2000.

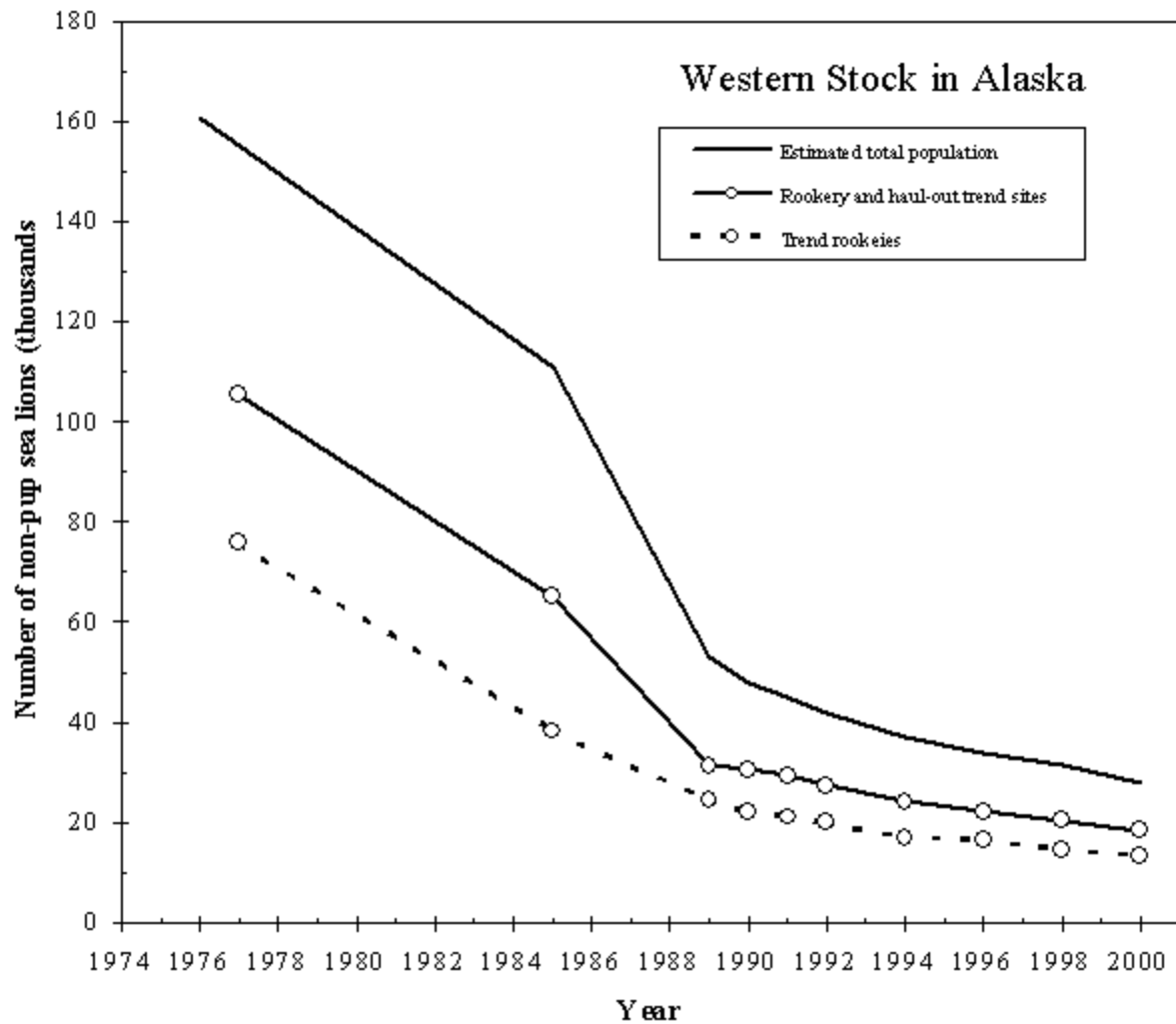


Figure 3.1-2 Regional Steller sea lion population trends, 1976-2000.

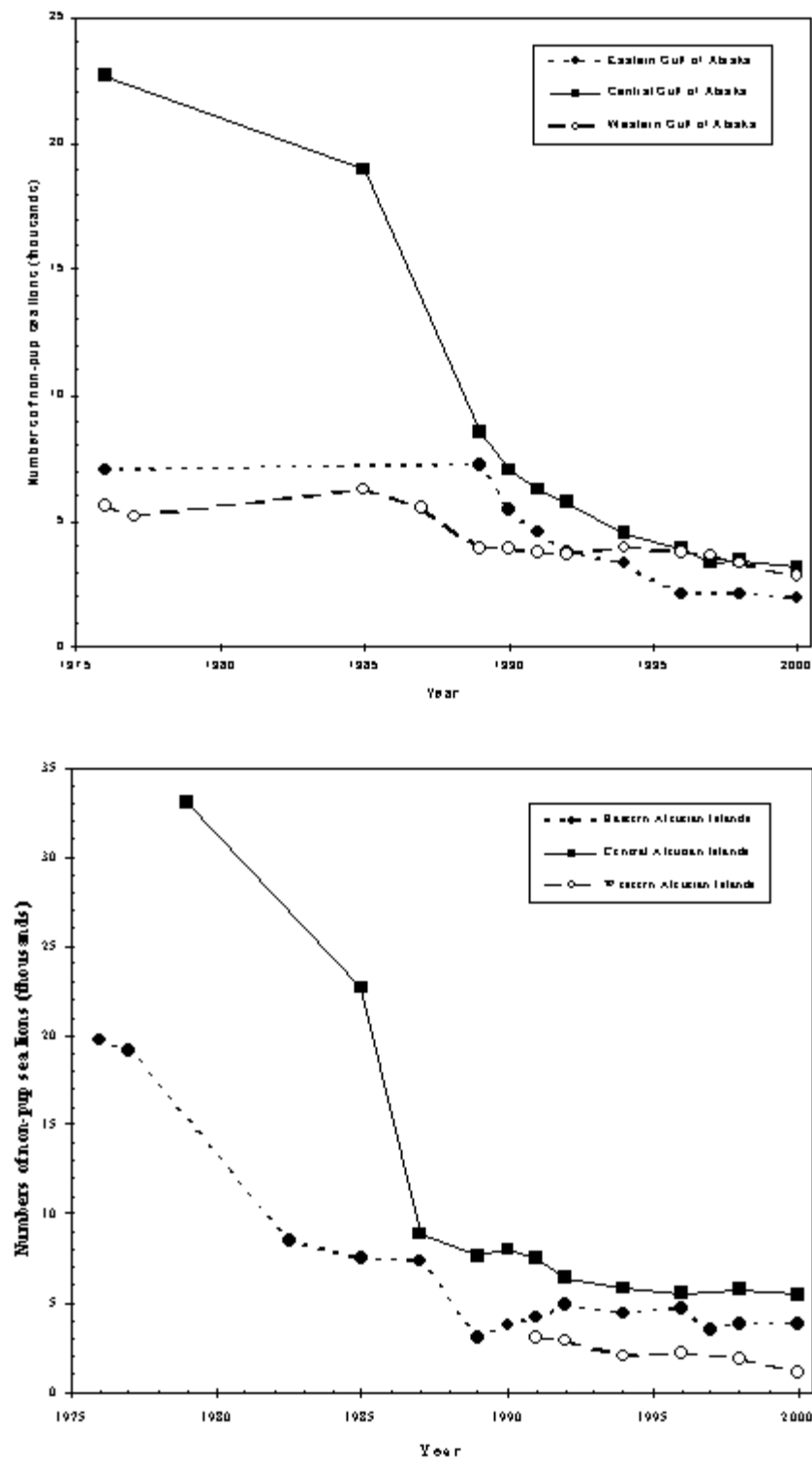


Figure 3.1-3 Counts of Steller sea lion pups in Alaska (Sease and Loughlin, 1999).

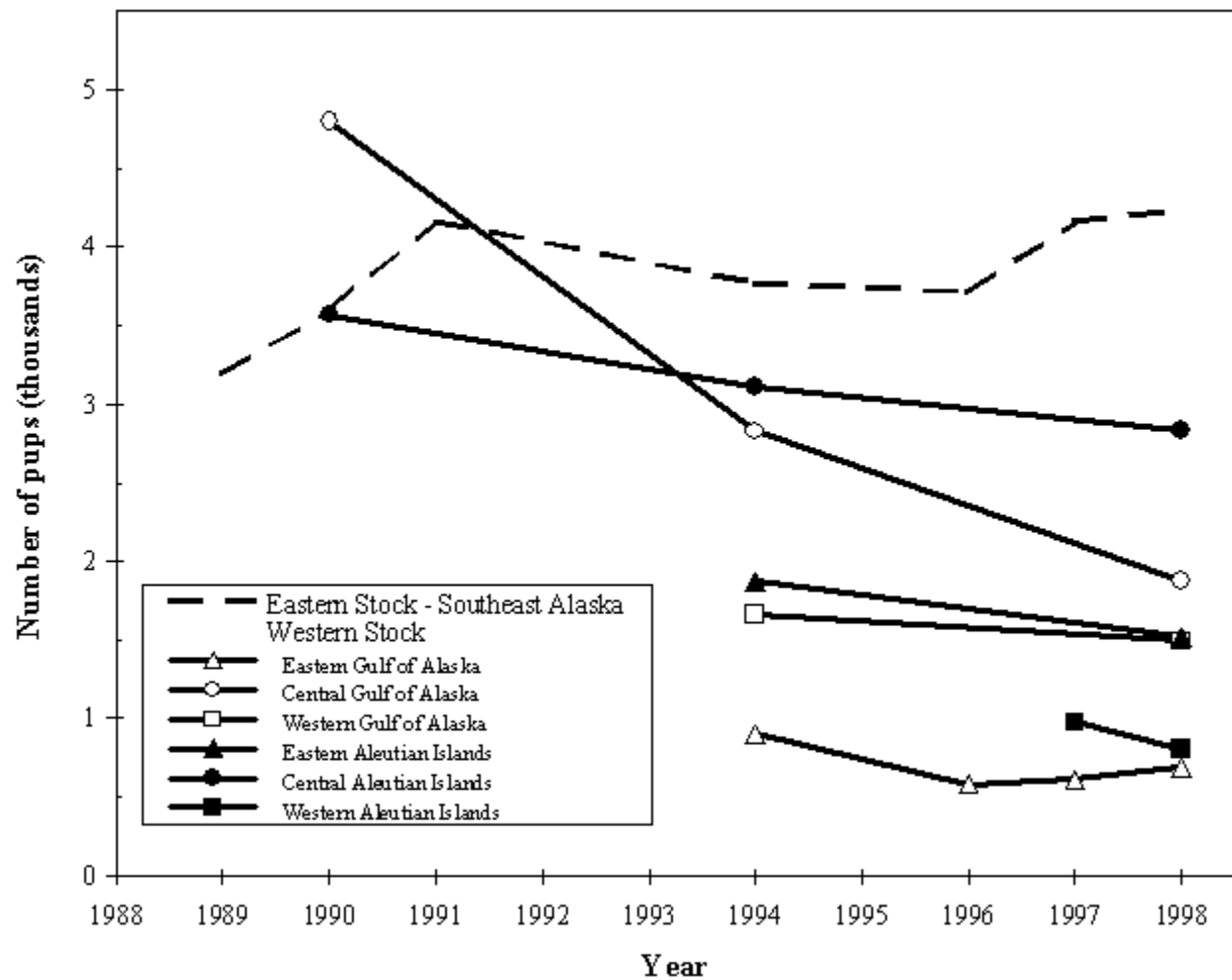


Figure 3.1-4 Population trends of Steller sea lion eastern stock in southeast Alaska, 1975-2000.

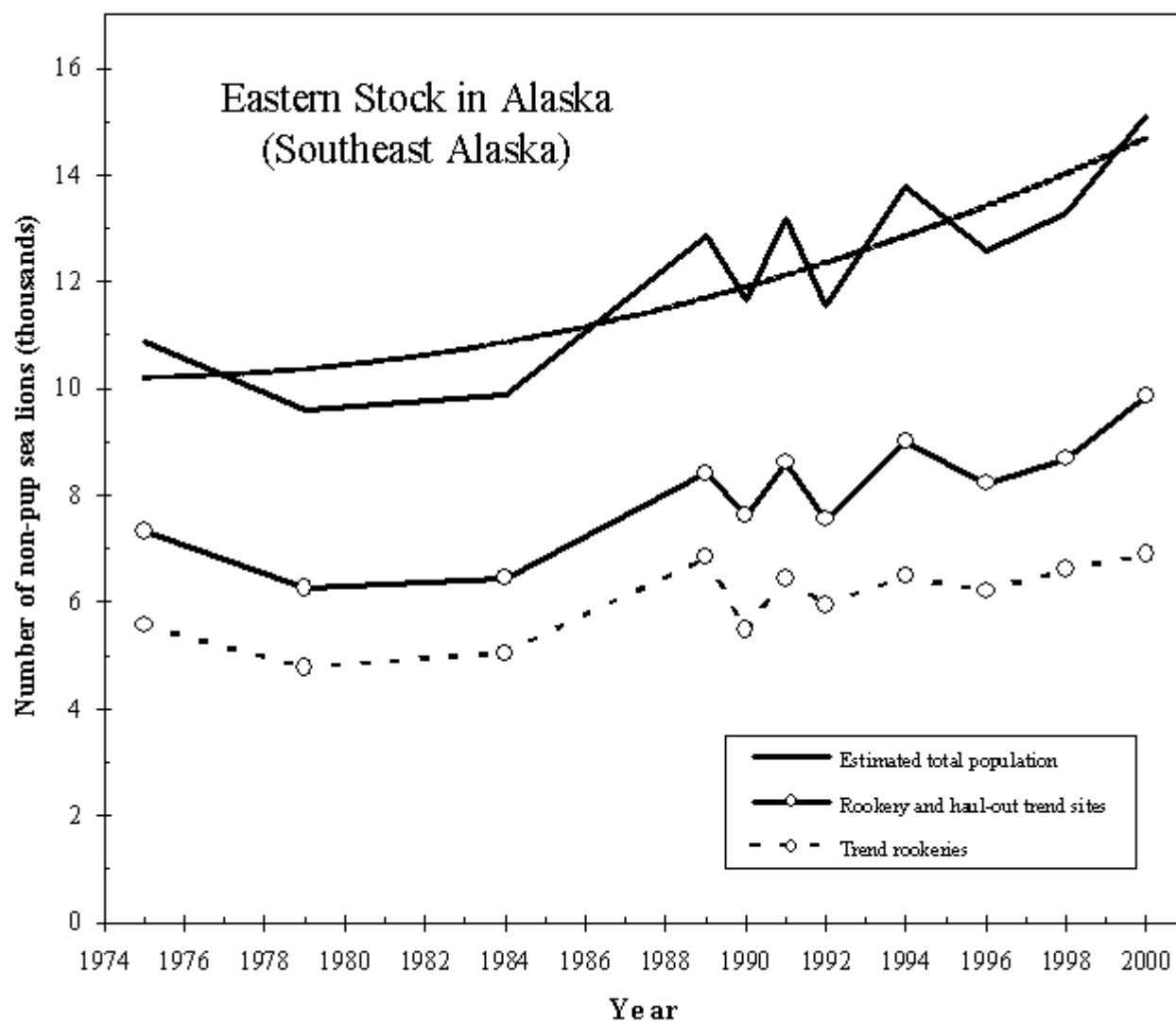


Figure 3.1-5 Counts of Steller sea lions in the eastern stock, 1982-1998 (adapted from Angliss *et al.*, 2001).

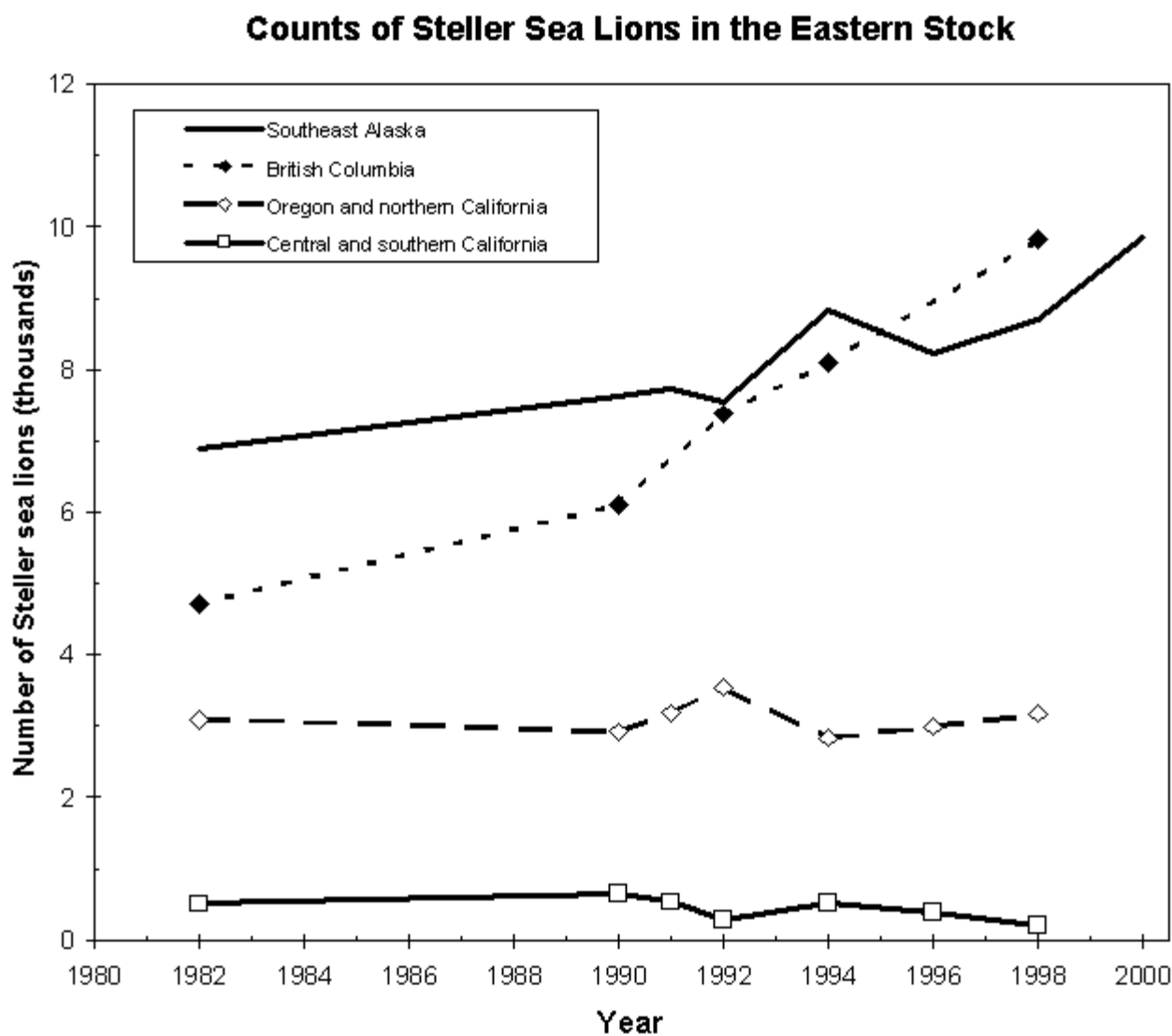


Figure 3.1-6 Distribution of Steller sea lions in the Bering Sea and Western/Central Gulf of Alaska from the Platform of Opportunity (POP) Database (NMFS Data).

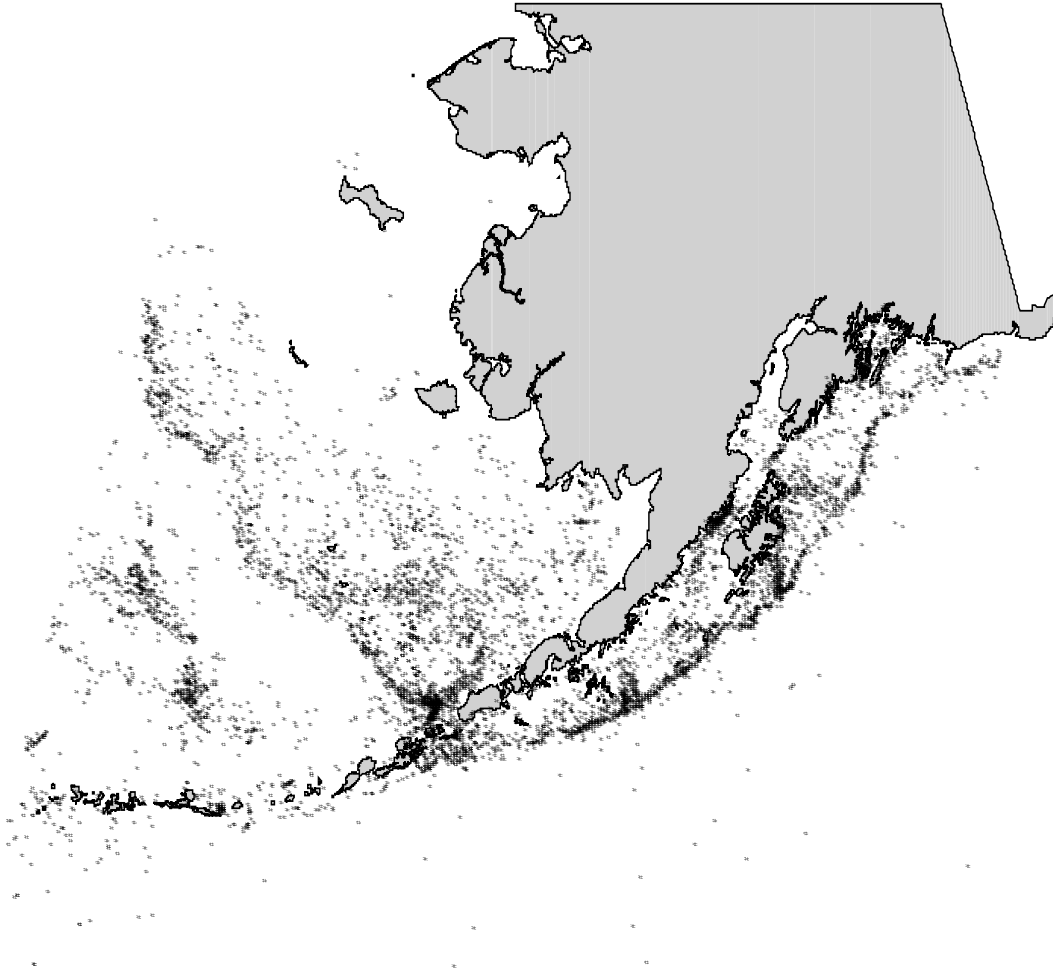


Figure 3.1-7 Proportion of dives by depth range for young-of-the-year (WYOY) and adult female Steller sea lions in summer (SAF) and winter (WAF) tracked during 1990-1993 (Merrick and Loughlin, 1997).

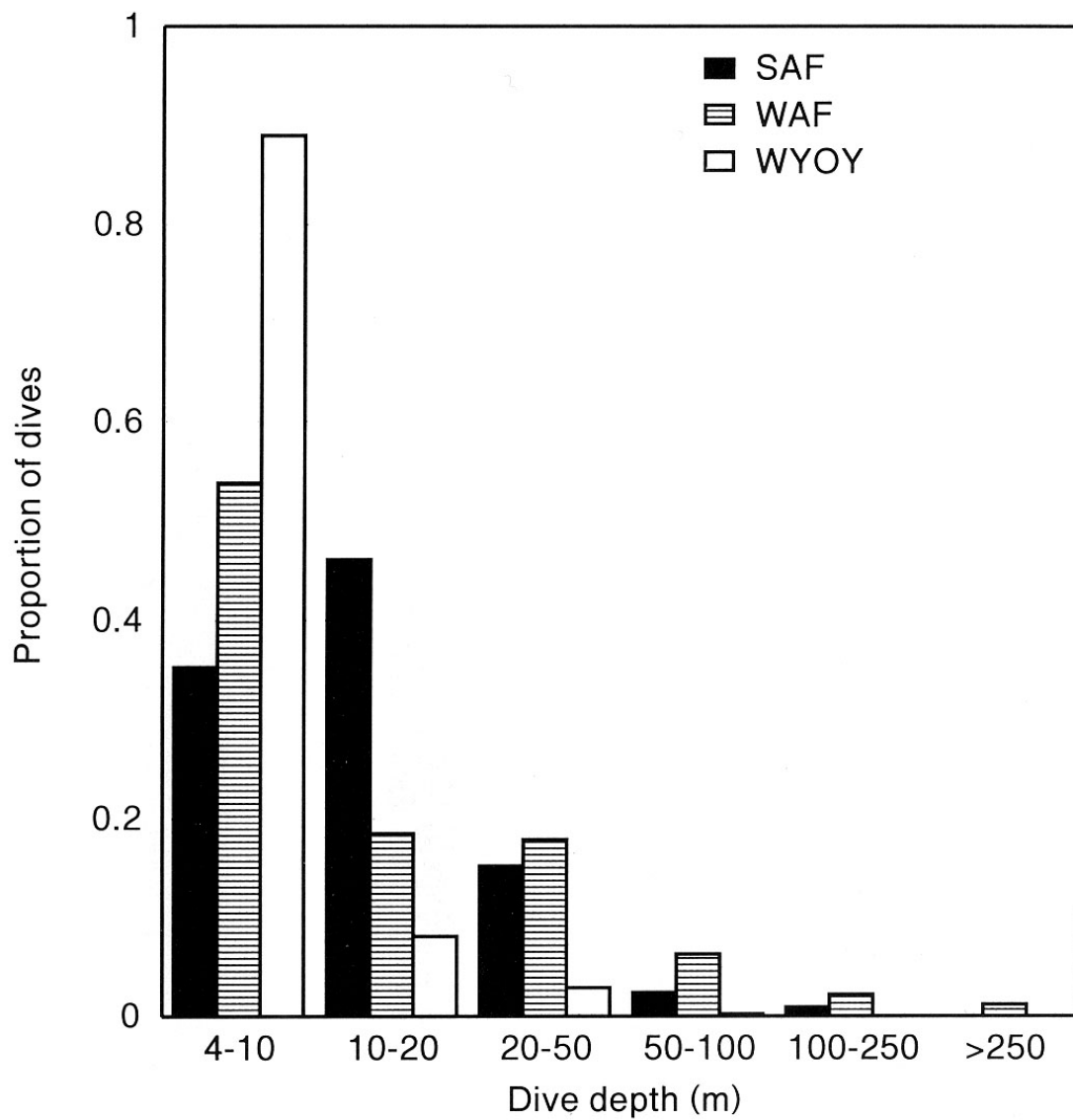
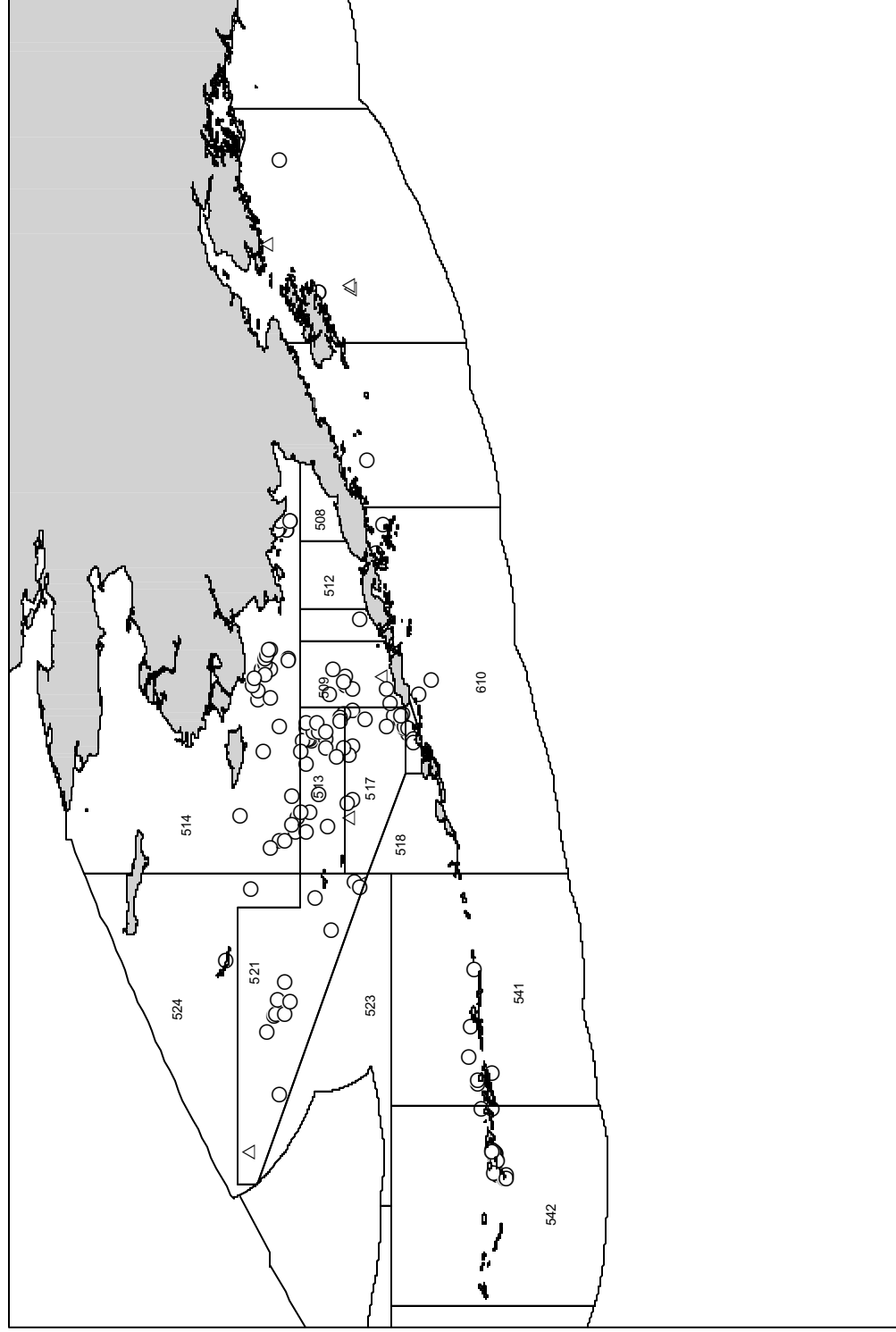


Figure 3.1-10 Locations of Observed Steller Sea Lions Incidentally Caught in Domestic Groundfish Trawl (circles) and Longline (triangles) Fisheries, 1989-1999.



3.2 Principal Target Groundfish Fish Species

In this section, descriptions are provided of the principal target groundfish species affected by proposed fisheries management changes under the Steller sea lion (SSL) protection measures alternatives; walleye pollock (Section 3.2.1), Pacific cod (Section 3.2.2), and Atka mackerel (Section 3.2.3). Information presented for these species includes a brief description of life history and stock structure, trophic interactions (particularly as related to SSL), the fishery, stock assessment, and the acceptable biological catch (ABC) as recommended in the most recent stock assessments. The ABC recommendations are described using the Tier system defined under Amendment 56 to the Bering Sea Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Groundfish Fisheries Management Plans. The information presented for each species supports the development of this SEIS and is not intended to be exhaustive.

Several other groundfish species are targeted in the Alaska groundfish fishery. These species are described in Section 3.2.4, but are not covered in great detail here as no changes in management directly affecting these species are proposed under this SEIS. Detailed information on these species and additional information on the principal target species described herein can be found in the following documents: Environmental Assessment for Essential Fish Habitat (NPFMC 1999a); Essential Fish Habitat Assessment Report for the Groundfish Resources of the Bering Sea and Aleutian Islands (BSAI) Region (NPFMC 1998a); Essential Fish Habitat Assessment Report for the Groundfish Resources of the Gulf of Alaska (GOA) Region (NPFMC 1998b); the year 2000 Stock Assessment and Fishery Evaluation Reports (SAFE Report) for the Groundfish Resources of the Bering Sea/Aleutian Islands and Gulf of Alaska Regions (NPFMC 2000a, 2000b); and the Draft Programatic SEIS (NMFS 2001a). Harvest data for all groundfish species for the year 2000 is available from NMFS (2001f).

3.2.1 Pollock

Walleye pollock (*Theragra chalcogramma*) is the most abundant groundfish species in the eastern Bering Sea (EBS) and the second most abundant groundfish stock in the GOA. It supports the largest fishery in Alaskan waters. Pollock is also known to be a major prey item of Steller sea lions. Concerns regarding the possible adverse effects of the fishery for pollock and other groundfish species on sea lions has prompted the development of this SEIS. Modification of the spatial and temporal distribution of the pollock fishery are central to this SEIS. For this reason pollock are covered in some detail here. More detailed information regarding the pollock and the pollock fishery is available in the Draft Programatic SEIS (NMFS 2001a) and the 2000 SAFE Reports (NPFMC 2000c, 2000d).

Stock Description and Life History

Pollock is the most abundant fish species within the eastern Bering Sea and the second most abundant groundfish stock in the GOA. It is widely distributed throughout the North Pacific Ocean in temperate and subarctic waters (Wolotira *et al.* 1993). Pollock is a semidemersal schooling fish, which becomes increasingly demersal with age. Approximately 50 percent of female pollock reach maturity at age four, at a length of approximately 40 cm. Pollock spawning is pelagic and takes place in the early spring on the outer continental shelf. In the EBS, the largest concentrations occur in the southeast, north of Unimak Pass. In the GOA, the largest spawning concentrations occur in Shelikof Strait and the Shumagin Islands (Kendall *et al.* 1996). Pollock are comparatively short-lived, with a fairly high natural mortality rate estimated at 0.3 (Hollowed *et al.* 1997; Weststad and Terry 1984) and maximum recorded age of around 22 years.

Although stock structure of Bering Sea pollock is not well defined (Wespestad 1993), three pollock stocks are recognized in the BSAI for management purposes: eastern Bering Sea, Aleutian Islands, and Aleutian Basin. Pollock in the GOA are thought to be a single stock (Alton and Megrey 1986) originating from springtime spawning in Shelikof Strait (Brodeur and Wilson 1996).

Trophic Interactions

The diet of pollock in the eastern Bering Sea has been studied extensively (Dwyer 1984; Lang and Livingston 1996; Livingston 1991a; Livingston and DeReynier 1996; Livingston *et al.* 1993). Juvenile pollock are pelagic and feed primarily on copepods and euphausiids. As they age, pollock become increasingly piscivorous and can be highly cannibalistic. Juvenile pollock is known to be the dominant fish prey of adult pollock in the EBS. Other fish consumed by pollock include juveniles of Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, rock sole, yellowfin sole, Greenland turbot, Pacific halibut, and Alaska plaice. On the shelf area, the contribution of these other fish prey to the diet of pollock tends to be very low (i.e., usually less than 2 percent by weight of the diet; (Livingston 1991a; Livingston and DeReynier 1996; Livingston *et al.* 1993). However, in the deeper slope waters, deep-sea fish (myctophids and bathylagids) are a relatively important diet component (12 percent by weight), along with euphausiids, pollock, pandalid shrimp, and squid (Lang and Livingston 1996).

The diet of pollock, particularly adults, in the GOA has not been studied as thoroughly as in the EBS. Larvae, 5–20 mm in length, consume larval and juvenile copepods and copepod eggs (Canino 1994; Kendall *et al.* 1987). Early juveniles (25–100 mm) primarily eat juvenile and adult copepods, larvaceans, and euphausiids; late juveniles (100–150 mm) eat mostly euphausiids, chaetognaths, amphipods, and mysids (Brodeur and Wilson 1996; Grover 1990; Krieger 1985; Livingston 1985; Merati and Brodeur 1997; Walline 1983). Juvenile and adult pollock in southeast Alaska rely heavily on euphausiids, mysids, shrimp, and fish as prey (Clausen 1983). Euphausiids are the dominant prey of GOA pollock, constituting a relatively constant proportion of the diet by weight across size classes. Shrimp and fish are the next two important prey items. Copepods are a less dominant food source (Yang 1993). Fish prey become an increasing fraction of GOA pollock diet with increasing size. A high diversity of species are preyed upon. Over 20 different fish species have been identified in the stomach contents of GOA pollock, with capelin being the dominant prey (Yang 1993). Commercially important prey species include Pacific cod, pollock, arrowtooth flounder, flathead sole, Dover sole, and Greenland turbot. In addition to capelin, forage fish including eulachon and Pacific sand lance were also found in pollock stomach contents.

Various studies have modeled pollock cannibalism and other sources of predation, particularly in the eastern Bering Sea (Dwyer 1984; Honkalehto 1989; Knechtel and Bledsoe 1981, 1983; Laevastu and Larkins 1981; Livingston 1991b, 1993, 1994; Livingston *et al.* 1993; Livingston and DeRenier 1996; Wespestad and Dawson 1992). Early efforts treated cannibalism in either a static or dynamic fashion. Trends in more recent efforts have used more standard stock assessment procedures such as virtual population analysis or integrated catch age models (Methot 1990). In summary, modeling efforts for pollock populations in total lead to the following conclusions regarding the effects of predation from cannibalism and other sources affecting recruitment and population dynamics:

- Cannibalism is a stabilizing influence on pollock populations. Modeled populations including cannibalism show less variation than when this factor is not included.
- Cannibalism is the largest source of juvenile predation, and is apparently responsible for observed declines in recruitment at high levels of pollock spawning biomass.

- In the current state of the EBS, cannibalism appears to be the most important source of predation mortality for age 0 and age 1 pollock.
- Predation mortality rates are not constant, varying across time with changes in predator abundance but perhaps also with heavier predation on more abundant year classes.
- Environmental factors such as surface currents are important determinants juvenile pollock survival, transporting larvae to areas with more or less favorable food availability and predation levels from adults or other sources.
- Availability of zooplankton prey is limiting, particularly for adult pollock.
- Under conditions simulating the current fishing mortality rate ($F = 0.3/\text{yr}^{-1}$) modeled pollock populations tend toward equilibrium.
- Maximization of average catch in the eastern Bering Sea occurs at a modeled fishing mortality rate approximately 10 times higher than the current F value ($F = 3.0/\text{yr}^{-1}$).

The modeling efforts summarized above, and the extent and dynamics of pollock cannibalism are described in more detail in the Alaska Groundfish Fishery Draft PSEIS (NMFS 2001a).

While cannibalism is the significant source of juvenile mortality in the EBS, several other groundfish predators are also important consumers. Other juvenile pollock predators include Greenland turbot, arrowtooth flounder, Pacific cod, halibut, and flathead sole (Livingston 1991b; Livingston and DeReynier 1996; Livingston *et al.* 1993). These species are some of the more abundant groundfish in the EBS, and pollock constitute a large proportion of their diets. Other less abundant species that consume pollock include Alaska skate, sablefish, Pacific sandfish, various sculpins, and small-mouthed flounders such as yellowfin sole and rock sole (Livingston 1989; Livingston *et al.* 1993; Livingston and DeReynier 1996). Age-0 and age-1 pollock are the targets of most of these predators, with the exception of Pacific cod, halibut, and Alaska skate, which may consume pollock ranging in age from age-0 to greater than age-6.

Unlike the EBS, the main source of predation mortality on GOA pollock at present appears to be from the arrowtooth flounder instead of cannibalism (Livingston 1994). Other dominant GOA groundfish populations that prey on pollock include sablefish, Pacific cod, and halibut (Albers and Anderson 1985; Best and St-Pierre 1986; Jewett 1978; Yang 1993). Pollock is one of the top five prey items (by weight) for Pacific cod, arrowtooth flounder, and halibut in this area. Other predators include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993). As in the eastern Bering Sea, halibut and Pacific cod tend to consume larger pollock, while arrowtooth flounder consume pollock that are mostly under age 3. Predation mortality on juvenile pollock in the GOA appears to be an increasingly controlling factor on recruitment. Prior to the ecological regime shift of the late 1970s, environmental factors controlling larval survival appeared to be the dominant factor controlling recruitment. Since this shift however, juvenile predation by expanding populations of predatory flatfish and cod has become the principal controlling factor.

Pollock is a major prey item for Steller sea lions in the GOA and the Bering Sea (Merrick and Calkins 1996; Pitcher 1980a, 1980b, 1981). In the GOA, pollock is a major prey of both juvenile and adult Steller sea lions. It appears that the proportion of animals consuming pollock increased from the 1970s to the 1980s, and this increase was most pronounced for juvenile Steller sea lions. Sizes of pollock consumed by GOA Steller sea lions range from 5 to 56 cm, and the size composition of pollock consumed appears to be related to the size composition of the pollock population. However, juvenile Steller sea lions consume smaller pollock on average than adults. Age 1 pollock was dominant in the diet of juvenile Steller sea lions in 1985, possibly a reflection of the abundant 1984 year class of pollock available to Steller sea lions in that year. In the Bering Sea, the preponderance of available data indicates that pollock and Atka mackerel are currently the two dominant prey species. Pollock is the principal prey year around in the Bering Sea out to the central Aleutian

Islands. In the Aleutian Islands, pollock is replaced by Atka mackerel as the major prey source (see Section 3.1.1.7).

Pollock is also significant prey item for other species of marine mammals in the eastern Bering Sea. Studies suggest that pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair *et al.* 1997 and 1994). The pollock consumed by fur seals are primarily age 0 and age 1 fish. Older age groups of pollock may appear in the diet, when young pollock are less abundant (Sinclair *et al.* 1997). Pollock has been noted as a prey item for other pinnipeds, including harbor seals, spotted seals, and ribbon seals. Harbor seals tend to have a variable diet and the pollock component varies with abundance. Spotted seals and ribbon seals feed on pollock in the winter and spring in the areas of drifting ice and pollock are their most common prey during these seasons (Lowry *et al.* 1997). Fin whales, minke whales, and humpback whales in the EBS are also known to be pollock predators. Stomach samples from the whale species have been very limited, so the importance of pollock in their diets has not been well-defined (Kajimura and Fowler 1984).

In the EBS, age 0 and age 1 pollock are variably the dominant component in the diets of northern fulmars, black-legged kittiwakes, common murre, and thick-billed murre. Red-legged kittiwakes also consume pollock but tend to rely more heavily on myctophids (Hunt *et al.* 1981; Kajimura and Fowler 1984; Springer *et al.* 1986). These species are the dominant avifauna of the eastern Bering Sea (Kajimura and Fowler 1984; Shuntov 1993). Fluctuations in chick production by kittiwakes have been linked to the availability of fatty fishes, such as myctophids, capelin, and Pacific sand lance (Hunt *et al.* 1995). Changes in the availability of prey, including pollock, to surface-feeding seabirds may be due to changes in sea surface temperatures and the locations of oceanographic features such as fronts, which could influence the horizontal or vertical distribution of prey (Decker *et al.* 1995; Springer 1992).

Research on the diets of marine mammals and birds in the GOA was less intensive than for the Bering Sea, but has recently been greatly accelerated (Brodeur and Wilson 1996; Calkins 1987; DeGange and Sanger 1986; Hatch and Sanger 1992; Lowry *et al.* 1989; Merrick and Calkins 1996; Pitcher 1980a, 1980b, 1981) (Section 3.5). The main piscivorous birds that consume pollock in the GOA are black-legged kittiwakes, common murre, thick-billed murre, tufted puffin, horned puffin, and probably marbled murrelets. The diets of common murre have been shown to contain around 5 percent to 15 percent age 0 pollock by weight, depending on the season. Both horned puffins and tufted puffins consume age 0 pollock (Hatch and Sanger 1992). The amount of pollock in the diet of tufted puffins varied by region in the years studied, with very low amounts in the north-central GOA and Kodiak Island areas, intermediate (5–20 percent) amounts in the Semidi and Shumagin Islands, and large amounts (25–75 percent) in the Sandman Reefs and eastern Aleutian Islands. The proportion of juvenile pollock in the diet of tufted puffins at the Semidi Islands varied by year and was related to pollock year-class abundance. Seabird reliance on pollock and other groundfish as prey is covered in more detail in Section 3.7.

The Fishery

Pollock supports the largest fishery in Alaskan waters. In the BSAI, pollock comprise 75–80 percent of the total annual catch. In the GOA, pollock constitute 25–50 percent of the catch. Fisheries management has restricted pollock to be harvested with pelagic trawl gear to minimize the potential interaction with other groundfish species and to reduce the magnitude of bottom disturbance. Pollock are also caught with bottom-trawl gear as bycatch from other fisheries.

The directed fishery for BSAI pollock is conducted by catcher-processors and catcher vessels using pelagic and bottom trawl gear. The season has traditionally been broken into two parts, a roe season during early winter, and a surimi (imitation crab) and filet season during the second half of the year. Currently, to minimize the potential indirect interaction with Steller sea lions, the seasons have been managed to occur over broader areas and over longer seasons. Observed pollock fishery trawl locations in 1999 by season are shown in Figure 3.2-1.

BSAI pollock are caught as bycatch in other directed fisheries, but because they occur primarily in well-defined aggregations, the impact of this bycatch is typically minimal. Recent discard rates through the early 1990s (discards/retained catch) of pollock in the directed fishery have been about 7–8 percent, reaching as high as 11 percent. In 1998, the discard rate dropped to 1.5 percent due to prohibitions on the discarding of pollock in fisheries where pollock are in bycatch-only status (trawl Pacific cod, rock sole, and yellowfin sole fisheries). In 1999, the discard rate was estimated at 3.0 percent (Iannelli *et al.* 2000).

In the GOA, major exploitable concentrations are found primarily in the Central and Western Regulatory Areas (147°W–170°W). Pollock from this region and the West Yakutat District are managed as a single stock that is separate from the BSAI pollock stocks (NPFMC 2000d). The pattern of the fishery generally reflects the broad spatial distribution of pollock throughout the central and western regions of the GOA. Shifts in the location of fishable concentrations of pollock reflect the seasonal migrations to spawning locations. The fishery generally occurs at depths between 100 and 200 m (Hollowed *et al.* 1997). Observed pollock fishery trawl locations in 1996 are shown in Figure 3.2-2. Important pollock fishery locations include Shelikof Strait, the canyon regions of the east side of Kodiak Island, and Shumagin Canyon.

Megrey (1989) documented the historical expansion of the pollock fishery in the GOA. He identified four phases of expansion, beginning with a developmental phase between 1964 and 1971 when the fishery was dominated by foreign trawlers that incidentally captured pollock in mixed-species catches. The second phase occurred between 1972 and 1980, when directed pollock harvests were initiated by foreign and joint-venture fisheries. Floating freezer-surimi trawlers were active in the GOA during the second phase of fishery development. The third phase of development occurred between 1981 and 1985. This phase was characterized by joint-venture operations. During this period, the Shelikof Strait spawning concentrations were discovered. Surimi production and roe harvest were emphasized during this phase of development. In recent years, foreign vessels have been eliminated from the pollock fishery. This final phase was marked by the passage of the inshore/offshore amendment, which mandated that 100 percent of the pollock catch be processed at shoreside plants. During this period the fishing community moved from a bottom trawl fishery to a pelagic fishery due to management measures established to control bycatch of prohibited species. Pacific halibut taken in the pollock fishery are added to the total for the shallow water complex halibut mortality cap. When the halibut cap is reached for the shallow water complex, trawling for species in the complex is prohibited, except for vessels using pelagic trawls.

In 2000, revised final Reasonable and Prudent Alternatives (RFRPAs) were implemented to reduce the potential for adverse modification of SSL foraging habitat (NMFS 1998b). The RFRPAs modify the TAC allocation in the BSAI and GOA to achieve this goal. Three types of measures were implemented in each area:

- Additional pollock fishery exclusion zones around sea lion rookery or haulout sites,
- Phased in reductions in the seasonal proportions of TAC that can be taken from critical habitat, and
- Additional seasonal TAC releases to disperse the fishery over time.

influences on larval mortality to increasing juvenile predation from expanding populations of predatory flatfish (Bailey and Macklin 1994; Bailey et al 1996; Bailey 2000; Bograd *et al.* 1994; Canino 1994; Hermann *et al.* 1996; Hollowed and Wooster 1995; Kendall *et al.* 1996; Megrey *et al.* 1996; Schumacher *et al.* 1993; Stabeno *et al.* 1995; Theilacker *et al.* 1996).

Acceptable Biological Catch as Recommended in the Most Recent Stock Assessments

Acceptable biological catch (ABC) and total allowable catch (TAC) limits relative to overfishing levels (OFLs) for the BSAI and GOA pollock stocks in 2001 are presented in Table 3.2-1. These values are based on the most recent stock assessments as reported in the Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI (Ianelli et al 2000) and the GOA (Dorn *et al.* 2000). The BSAI has been split into three separate areas for identification of ABC; EBS, Aleutian Islands, and Bogoslof. ABC and TAC determination for each area are discussed further below.

Based on information available for projecting harvest alternatives in 2000, estimates of maximum sustainable yield (MSY) were available for the EBS pollock stock which would allow for classification under Tier 1 of the ABC and overfishing levels (OFL) definitions. The fishing mortality used to set ABC (F_{ABC}) may be less than this level, but not greater. However, given that the reliability of the reference points used to set MSY was questionable, the option was retained to classify the pollock stock under either Tier 1a or Tier 3a of the ABC/OFL definitions (Ianelli *et al.* 2000).

The estimate of biomass of spawning female pollock for the EBS in 2001 is 2.761 million metric tons (mt). This was well above the $B_{40\%}$ value of 2.426 million tons. Under Tier 1a, this equates to a max ABC of 2.125 million mt. Under Tier 3a, this equates to a max ABC of 1.842 million mt, relative to an OFL of 3.536 million mt. The total stock biomass (age 3+) is estimated at 10.5 million mt (Ianelli *et al.* 2000). The more conservative ABC was selected for 2001 to provide stability for the fishery, provide added conservation for SSL protection, and to compensate for uncertainty regarding unknown levels of pollock harvest in Russian waters. This corresponds to a TAC of 1.4 million mt for the BSAI in 2001 (Table 3.2-1).

Separate OFL, ABC, and TAC levels were calculated for the Aleutian Island and Bogoslof District components of the EBS pollock stock per request of the (NPFMC) plan team. Current information indicates that these fish belong to the same group of 4 to 5 year old adults which are distinct from the EBS stock, partitioned primarily by age structure (although not necessarily a genetically distinct stock). This separation appears to be density dependent, driven by the influences of strong year classes on the surrounding shelves in the US or Russian EEZ. Due to limited information, these “stocks” are managed under Tier 5 of the ABC/OFL definitions. Based on available information, the ABC for the Aleutian Island stock for 2001 is set at 23,800 mt. The TAC for this area is set at 2,000 mt, well below the estimated OFL of 31,700 mt. The ABC for the Bogoslof region in 2001 is set at 8,470 mt. The TAC is set at 1,000 mt, again well below the estimated OFL of 60,200 mt. The same TACs were set for both areas in 2000, and incidental catch of pollock (the only source of fishing mortality) was well below these levels (Table 3.2-1).

In 2000, GOA pollock east of 140 W longitude fell into subtier “b” of Tier 3 of the ABC/OFL definitions, which require reliable estimates of biomass, $B_{40\%}$, and fish mortality $F_{30\%}$ and $F_{40\%}$ (Dorn *et al.* 2000). Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawner stock biomass to 35 percent of its unfished level (the $F_{35\%}$ rate). Spawning biomass in 2001 was projected to be 204,600 mt, which is less than $B_{40\%}$. This translated to a recommended 2001 ABC of 99,350 mt for the combined W/C/WYK area, and a corresponding TAC of 89,615 mt for the area. In the Southeast Outside District pollock fell into Tier 5, OFL was set at 8,160 mt and ABC and TAC levels were set at 6,460

mt. Gulfwide OFL, ABC, and TAC levels are presented in Table 3.2-1. Current harvest rates were set to ensure a healthy spawning stock, large enough to ensure successful recruitment over long time and recruitment variations in both the BSAI and GOA..

Table 3.2-1 Estimated Overfishing Levels (OFL), Acceptable Biological Catch (ABC), and Total Acceptable Catch (TAC) for Pollock in the BSAI and GOA for 2001, and Total Catch Figures for 2000 by Area (all values in metric tons)

Area	<u>OFL</u>	<u>ABC</u>	<u>TAC</u>	<u>2000 Catch</u>
Eastern Bering Sea	3,536,000	1,842,000	1,400,000	1,019,067
Aleutian Islands	31,700	23,800	2,000	1,174
Bogoslof	60,200	8,470	1,000	29
Gulf of Alaska	126,360	105,810	95,875	71,877

Source: National Marine Fisheries Service - Alaska Regional Office, fishery updates and reports, available at <http://www.fakr.noaa.gov>

3.2.2 Pacific Cod

Pacific cod (*Gadus macrocephalus*) is an important fishery in both the BSAI and GOA. It is the second largest groundfish fishery overall. Pacific cod is known to be important prey for Steller sea lions year around, becoming more significant during winter months when salmon are less available (see Section 3.1.1.7.3). Concerns regarding the possible adverse effects of the fishery for Pacific cod and other groundfish species on sea lions has prompted the development of this SEIS. Modification of the spatial and temporal distribution of the Pacific cod fishery are central to the alternatives analyzed in this SEIS. Hence this species is described in additional detail. More detailed information on the Pacific cod fishery is available in the Draft Programmatic SEIS (NMFS 2001a) and the SAFE Reports for 2000 (NPFMC 2000c, 2000d).

Stock Description and Life History

Pacific cod is a demersal species that occurs on the continental shelf and upper slope from Santa Monica Bay, California through the GOA, Aleutian Islands, and EBS to Norton Sound (Bakkala 1984). The Bering Sea represents the center of greatest abundance, although Pacific cod are also abundant in the GOA and Aleutian Islands. GOA, Bering Sea, and Aleutian Islands cod stocks are genetically indistinguishable (Grant *et al.* 1987), and tagging studies show that cod migrate seasonally over large areas (Shimada and Kimura 1994).

Pacific cod spawn in the late winter, massing in large spawning aggregations over relatively small areas. Major aggregations occur between Unalaska and Unimak Islands, southwest of the Pribilof Islands, and near the Shumagin group in the western GOA (Shimada and Kimura 1994). Spawning takes place in the sublittoral-bathyal zone near the bottom—the area of the continental shelf and slope about 40–290 m deep. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983).

Pacific cod reach a maximum recorded age of 19. Estimates of natural mortality vary widely, ranging from 0.29 (Thompson and Shimada 1990) to 0.83–0.99 (Ketchen 1964). For stock assessment purposes, a value of 0.37 is used in both the BSAI (Thompson *et al.* 1999) and the GOA (Thompson and Dorn 1999). In the BSAI, 50 percent of Pacific cod are estimated to reach maturity by the time they reach 67 cm in length, or

an age of about 5 years (Thompson and Dorn 1999). The same length in the GOA stock corresponds to an age of about 7 years (Thompson *et al.* 1999)

Trophic Interactions

Pacific cod are omnivorous. In the BSAI and GOA, in terms of percent occurrence, the most important items were polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important items were euphausiids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important items were pollock, fishery offal, and yellowfin sole. Small Pacific cod were found to feed mostly on invertebrates, while large Pacific cod are mainly piscivorous (Livingston 1991a). Predators of juvenile Pacific cod include pollock and the predatory flatfishes. Adult Pacific cod are preyed upon by halibut and salmon shark. Marine mammal predators include Steller sea lions, northern fur seals, harbor porpoises, various whale species, and tufted puffins (Westrheim 1996).

Frequency of occurrence (FO) analyses of Pacific cod in the diet of Steller sea lions indicate that overall Pacific cod is a major prey item behind pollock, Atka mackerel, and salmon. During winter months when salmon are less available, the FO of cod in sea lion diet increases. Studies of winter diet indicate that Pacific cod have become a top prey item for both the western stock and the eastern stock of Steller sea lions since the 1970s (see Section 3.1.1.7.3).

Fishery

The Pacific cod fishery is the second largest Alaskan groundfish fishery. In 2000, Pacific cod constituted 12 percent of the groundfish catch in the BSAI and 27 percent of the groundfish catch in the GOA. The fishery for Pacific cod is conducted with bottom trawl, longline, pot, and jig gear. Of these, the fishery conducted with jig gear is by far the smallest. More than 100 vessels participate in each of the three larger fisheries. The age at 50 percent recruitment to the fishery varies between regions. For trawl, longline, and pot gear, the ages at 50 percent recruitment in the EBS are approximately four and five years, respectively (Thompson *et al.* 1999, 2000). For all three gears, the age at 50 percent recruitment in the GOA is approximately six years (Thompson and Dorn 1999, 2000). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run essentially year-round. Bycatch of crab and halibut often causes the Pacific cod fisheries to close prior to reaching the TAC. In the EBS, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagins. Pacific cod is also taken as bycatch in a number of trawl fisheries. In the EBS, Pacific cod is taken as bycatch in the trawl fisheries for pollock, yellowfin sole, and rock sole. In the Aleutian Islands region, Pacific cod is taken as bycatch in the trawl fishery for Atka mackerel. In the GOA, Pacific cod is taken as bycatch in the trawl fisheries for shallow water flatfish, arrowtooth flounder, and flathead sole. Since 1998, discarding of Pacific cod has been prohibited except in fisheries which Pacific cod has bycatch only status.

Stock Assessment

Beginning with the 1993 BSAI SAFE report (Thompson and Methot 1993) and the 1994 GOA SAFE report (Thompson and Zenger 1994), a length-based synthesis model (Methot 1990) has formed the primary analytical tool used to assess Pacific cod. Although the Pacific cod stocks in the EBS and GOA are modeled separately, the model structures in recent years have been identical (Thompson and Dorn 2000; Thompson

et al. 2000). No formal assessment model exists for the Aleutian Islands portion of the BSAI stock. Instead, results from the EBS assessment are inflated proportionally to account for Aleutian Islands fish.

Annual trawl surveys in the EBS and triennial trawl surveys in the Aleutian Islands and GOA are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and Dorn 2000; Thompson *et al.* 2000). For the most recent assessments, fishery size compositions were available, by gear, from Aleutian Islands bottom trawl surveys for the years 1978 through 1997. For the year 2000 stock assessment, size composition data from the 2000 eastern Bering Sea bottom trawl surveys were incorporated.

The catch history was divided into two portions, determined by the relative importance of the domestic fishery. A *pre-domestic* portion was defined as those years in which the domestic fishery took less than half the catch, and a *domestic* portion was defined as those years in which the domestic fishery took at least half the catch. Within each year (in both portions of the time series), catches were divided according to three time periods: January–May, June–August, and September–December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). Four fishery size composition components were included in the likelihood functions used to estimate model parameters: the period 1 trawl fishery, the periods 2–3 trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size composition components, likelihood components for the size composition and biomass trend from the bottom trawl surveys were included in the model. All components were weighted equally.

Quantities estimated in the most recent stock assessments include parameters governing the selectivity schedules for each fishery and survey in each portion of the time series, parameters governing the length-at-age relationship, population numbers at age for the initial year in the time series, and recruitments in each year of the time series. Given these quantities, plus parameters governing natural mortality, survey catchability, the maturity schedule, the weight-at-length relationship, and the amount of spread surrounding the length-at-age relationship, the stock assessments reconstruct the time series of numbers at age and the population biomass trends (measured in terms of both total and spawning biomass). The model around which the most recent Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates. Based on these projections, the scientists responsible for conducting the assessments recommend a pair of ABC values for the coming year (one value for the BSAI and one for the GOA).

ABC as Recommended in the Most Recent Stock Assessments

Acceptable biological catch (ABC) and total allowable catch (TAC) limits relative to overfishing levels (OFLs) for the BSAI and GOA Pacific cod stocks in 2001 are presented in Table 3.2-2. These values are based on the most recent stock assessments as reported in the Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the BSAI (Thompson *et al.* 2000), and the GOA (Thompson and Dorn 2000). The determination of ABC and TAC for each stock is described further below.

Pacific cod is currently managed under Tier 3 of the ABC/OFL definitions. Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). The maximum permissible ABC depends on the relationship of projected spawning biomass to $B_{40\%}$. For the BSAI, the base model in the 2000 assessment projected a 2001 spawning biomass of 315,000 mt, about 19 percent below the $B_{40\%}$ estimate of 389,000 mt, leading to a maximum permissible ABC of 214,000 mt (Thompson and Dorn

2000). For the GOA, the base model in the 2000 assessment projected a 2001 spawning biomass of 93,800 mt, about 5 percent above the $B_{40\%}$ estimate of 89,600 mt, leading to a maximum permissible ABC of 76,700 mt (Thompson *et al.* 1999, 2000). In contrast to prior years, the analysis of statistical uncertainty used as the basis for a risk-averse ABC recommendation was not applied. Instead, the ratio between the recommended F_{ABC} and $F_{40\%}$ in 2000 (0.87) was assumed to apply to 2001 as well. This ratio was applied to the maximum permissible value of F_{ABC} rather than $F_{40\%}$. These analyses resulted in recommended ABCs of 188,000 mt in the BSAI and 67,800 mt in the GOA (see Table 3.2-2).

Table 3.2-2 Estimated Overfishing Levels (OFL), Acceptable Biological Catch (ABC), and Total Acceptable Catch (TAC) for Pacific Cod in the BSAI and GOA for 2001, and Total Catch Figures for 2000, by Area (all values in metric tons)

<u>Area</u>	<u>OFL</u>	<u>ABC</u>	<u>TAC</u>	<u>2000 Catch</u>
Bering Sea/ Aleutian Islands	248,000	188,000	188,000	177,435
Gulf of Alaska	91,200	67,800	52,100 (excluding state waters)	54,493

3.2.3 Atka Mackerel

Atka mackerel (*Pleurogrammus monopterygius*) is a significant fishery in the Aleutian Islands region, where it is pursued by midwater and bottom trawls in relatively shallow water. The abundance of Atka mackerel in the GOA is limited and their distribution is patchy. Atka mackerel is known to be a major prey item of Steller sea lion in the central and western Aleutian Islands throughout year, although its importance declines in winter. Concerns regarding the possible adverse effects of the fishery for Atka mackerel and other groundfish species on sea lions has prompted the development of this SEIS. Modification of the spatial and temporal distribution of the Atka mackerel fishery are central to the alternative analyzed in this SEIS. Hence this species is described in additional detail. More detailed information on the Atka mackerel fishery is available in the Draft Programmatic SEIS (NMFS 2001a) and the SAFE Reports for 2000 (NPFMC 2000c, 2000d).

Stock Description and Life History

Atka mackerel are distributed from the east coast of the Kamchatka Peninsula, throughout the Aleutian Islands and the EBS, eastward through the GOA to southeast Alaska (Wolotira *et al.* 1993). Their current center of abundance is in the Aleutian Islands, with marginal distributions extending into the southern Bering Sea and into the western GOA. Atka mackerel are one of the most abundant groundfish species in the Aleutian Islands, where they are the target of a directed trawl fishery (Lowe *et al.* 2000). Adults are semipelagic and spend most of the year over the continental shelf in depths generally less than 200 m. Adults migrate annually to shallow coastal waters during spawning, forming dense aggregations near the bottom (Morris 1981; Musienko 1970). In Russian waters, spawning peaks in mid-June (Zolotov 1993) and in Alaskan waters in July through October (McDermott and Lowe 1997). Females deposit adhesive eggs in nests or rocky crevices. The nests are guarded by males until hatching occurs (Zolotov 1993). The first *in situ* observations of spawning habitat in Seguam Pass were documented in August, 1999.¹ Genetic studies

¹Robert Lauth, "Personal Communication," NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

indicate that Atka mackerel form a single stock in Alaskan waters (Lowe *et al.* 1998). However, growth rates can vary extensively among different areas (Kimura and Ronholt 1988; Lowe *et al.* 1998; Lowe and Fritz 2000). Age and size at 50 percent maturity has been estimated at 3.6 years and 33–38 cm, respectively (McDermott and Lowe 1997). Atka mackerel are a relatively short-lived groundfish species. A maximum age of 15 years has been noted, however most of the population is probably less than 10 years old. Natural mortality estimates vary extensively, and estimates have ranged from 0.12 to 0.74 as determined by various methods. For stock assessment purposes, a value of 0.3 is used (Lowe *et al.* 2000).

An Atka mackerel population existed in the GOA primarily in the Kodiak, Chirikof, and Shumagin areas, and supported a large foreign fishery until the early 1980s. By the mid-1980s the fishery, and presumably the population had disappeared. Over this same period Atka mackerel bycatch in other groundfish fisheries declined sharply, further evidence of the loss of the population. This dramatic decline suggests that the GOA may be at the edge of the species range and may only be populated during periods when recruitment, probably as juveniles, from the Aleutian Islands portion of their range is strong (Lowe and Fritz 2000).

Trophic Interactions

Yang (1996) found that more than 90 percent of the total stomach content (by weight) of Atka mackerel in Aleutian Islands was made up of invertebrates, with less than 10 percent made up of fish. Euphausiids (mainly *Thysanoessa inermis* and *T. rachii*) were the most important prey items, followed by calanoid copepods. The two species of euphausiids comprised 55 percent of the total stomach contents, and copepods comprised 17 percent. Larvaceans and hyperiid amphipods had high FO levels (81 percent and 68 percent, respectively), but comprised less than 8 percent of the total stomach content weight. Squid was another item in the diet of Atka mackerel; it had a FO of 31 percent, but comprised only 8 percent of total stomach content. Atka mackerel are known to eat their own eggs. Yang (1996) found that Atka mackerel eggs comprised 3 percent of the total stomach content and occurred in 9 percent of the analyzed Atka mackerel stomachs. Walleye pollock were the second most important prey fish of Atka mackerel, comprising about 2 percent of the total stomach content. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were minor components of the Atka mackerel diet; each category comprised less than 1 percent of the total stomach content. Atka mackerel diet in the GOA has not been studied extensively. However, it is probably a reasonable assumption that the major prey items of GOA Atka mackerel would likely be euphausiids and copepods as was found in Aleutian Islands Atka mackerel (Yang 1996).

Atka mackerel are an important component in the diet of other commercial groundfish in the Aleutian Islands, mainly arrowtooth flounder, Pacific halibut, and Pacific cod. The importance of Atka mackerel as groundfish prey in the GOA is minimal (Yang 1993). Seabirds, mainly tufted puffins, followed by thick-billed murrelets, and horned puffins prey on Atka mackerel. Marine mammals, mainly northern fur seals and Steller sea lions, also prey on Atka mackerel, as well as harbor seals and Dall's porpoise (Byrd *et al.* 1992; Livingston *et al.* 1993; Fritz *et al.* 1995; Yang 1996).

Atka mackerel is a major prey species year around for Steller sea lions in the BSAI, becoming the dominant species from the central Aleutian Islands west. However, the importance of Atka mackerel in their diet declines in winter, when the availability of cod and pollock increase (see Section 3.1.1.7.3).

The Fishery

The directed fishery for Atka mackerel is prosecuted by catcher/processor bottom trawlers. The fishery patterns generally reflect species behavior in that the fishery is highly localized, occurring in the same few

locations each year, generally at depths between 100 and 200 m (Lowe and Fritz 1999). Observed Atka mackerel fishery trawl locations during 1998 and 1999 in the Aleutian Islands are shown in Figures 3.2-3 and 3.2-4. Important Atka mackerel fishery locations include Seguam Bank, Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the seamounts and reefs near Buldir Island.

Since 1979, the Atka mackerel fishery has occurred largely within areas designated as Steller sea lion critical habitat. While total removals from critical habitat may be small in relation to total biomass estimates in the Aleutian Islands, fishery harvest rates in localized areas may have been high enough to affect the availability of prey to Steller sea lions (Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel apparently does not affect fishing success from one year to the next, since local Aleutian Islands populations appear to be replenished by immigration and recruitment. However, this pattern could create temporary reductions in the size and density of localized Atka mackerel populations, which could affect Steller sea lion foraging success during the time the fishery is operating and for a period of unknown duration after the fishery is closed.

To address the possibility that the fishery creates localized depletions of Atka mackerel and adversely modifies Steller sea lion critical habitat by disproportionately removing prey, the Council passed a fishery management regulatory amendment that proposed a four-year timetable to temporally and spatially disperse and reduce the level of Atka mackerel fishing within Steller sea lion critical habitat in the BSAI in June 1998. The temporal dispersion is accomplished by dividing the BSAI Atka mackerel TAC into two equal seasonal allowances. The first allowance is made available for directed fishing from January 1 to April 15 (A season), and the second seasonal allowance is made available from September 1 to November 1 (B season). The spatial dispersion is accomplished through maximum catch percentages of each seasonal allowance that can be caught within Steller sea lion critical habitat as specified for the central and western Aleutian Islands. No critical habitat closures are established for the eastern subarea, but the 20-nm trawl exclusion zones around the Seguam and Agligadak rookeries that have been in place only for the pollock A-season, are in effect year-round. The regulations implementing these management changes became effective January 22, 1999. The four-year timetable for spatial dispersion of the Atka mackerel fishery outside of critical habitat is presented in Table 3.2-3.

The rapid depletion of the GOA Atka mackerel population could have adversely affected western stock Steller sea lion foraging success, which raised concerns regarding how the fishery may have affected food availability and the potential for recovery of the sea lion populations. There has not been a directed Atka mackerel fishery in the GOA since 1996.

Table 3.2-3 Timetable for Spatial Dispersion of total allowable catch (TAC) of Atka Mackerel in Steller Sea Lion Critical Habitat (CH) in the Aleutian Islands

Year(s)	Area 542(TAC)		Area 543(TAC)	
	Inside CH	Outside CH	Inside CH	Outside CH
1999	80%	20%	65%	35%
2000	67%	33%	57%	43%
2001	54%	46%	49%	51%
2002	40%	60%	40%	60%

CH = Critical Habitat

Relative to 1998, the biggest shift in the distribution of fishing effort was observed in Area 542, where effort shifted to Petral Bank in 1999 (Figure 3.2-4).

Atka mackerel are not commonly caught as bycatch in other directed fisheries. The largest amounts of discards, which are likely undersized fish, occur in the directed Atka mackerel trawl fisheries. Recent discard rates (discards/retained catch) of Atka mackerel in the directed fishery have been below 10 % (Lowe *et al.* 2000). Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish (primarily Pacific ocean perch, sharpchin, and northern rockfish) fisheries. It is difficult to discern the level of natural bycatch of Atka mackerel in the rockfish fisheries, as vessels may actually be targeting Atka mackerel in particular hauls, but overall they are designated as targeting rockfish on a particular trip. In 1998, 4,597 mt of Atka mackerel were discarded in the directed rockfish fishery as compared to 1,072 mt discarded in all other fisheries (Lowe *et al.* 2000).

Stock Assessment

Atka mackerel are a difficult species to survey because they do not have a swim bladder and are therefore poor targets for hydroacoustic surveys. They prefer rough and rocky bottoms that are difficult to sample with the current survey gear, and their schooling behavior and patchy distribution result in survey estimates with large variances. Complicating the difficulty in surveying Atka mackerel is the low probability of encountering schools in the GOA, where the abundance is lower and their distribution is patchier relative to the BSAI. Because of this, it has not been possible to estimate population trends for the species in the GOA in recent years. The stock assessment in the Aleutian Islands is based on NMFS triennial trawl surveys, as well as total catch and catch at age data from the commercial fishery.

BSAI Atka mackerel are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Fishery catch statistics (including discards) are estimated by the NMFS Regional Office. These estimates are based on the best blend of observer reported catch and weekly production reports. Stock assessments include catch history, characterizations of the fishery, key life history parameters, survey and model-estimated abundance trends, historical exploitation rates, reference fishing mortality rates, projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions, and a recommended harvest rate and catch for the upcoming year. The results of the analyses, which are updated annually, are presented in the BSAI Atka mackerel stock assessment, which is incorporated into the BSAI Stock Assessment and Fishery Evaluation report.

The 2000 age and size distributions of BSAI Atka mackerel are discussed by Lowe *et al.* (2000). As of 2000, the age composition of the stock is dominated by strong year classes in 1998 (2-year-olds) and 1995 (5-year-olds), and there is still evidence of the strong 1992 year class (8-year-olds) in the population. The estimated mean age of the 2000 Aleutian Islands population is 5.0 years. The current fishery tends to select fish aged 3 to 12 years old (Lowe and Fritz 1999). It is not known how the age composition of the population would look in an unfished population.

The temporal distribution of the BSAI Atka mackerel stock is an issue of concern for the purpose of seasonal TAC apportionment relative to estimates of groundfish prey consumption by Steller sea lions. Specifically, it is desirable to incorporate knowledge of the seasonal abundance of Atka mackerel in critical habitat when evaluating alternatives for setting TACs by area and season. Biomass estimates of Atka mackerel are available on an annual basis from the stock assessment (Lowe *et al.* 2000). However, these stock assessments do not provide sufficient information to determine the temporal and spatial distribution of biomass in critical habitat. The groundfish surveys which examine biomass distribution in the Aleutian

Islands are also limited. They are only conducted every 3 years, and only in the summer (May-August), and the survey design does not allow for evaluation of biomass data within critical habitat alone. Therefore, there is no direct information on which to base spatial or temporal estimates of Atka mackerel biomass distribution in the Aleutian Islands.

Despite these limitations, other sources of information can be used to estimate Atka mackerel biomass inside critical habitat on a monthly basis. Specifically, knowledge of the general habitat distribution of Aleutian Islands Atka mackerel, and the temporal and spatial distribution of the stock can be used to infer the monthly biomass distribution. Survey data indicates that the effective limit of Atka mackerel habitat in the Aleutian Islands is confined to depths of less than 200 m, the depth limit of the shelf area. An average of less than 1% of the total Atka mackerel biomass estimated from the 1980 to 2000 trawl surveys was found at greater than 200 m (Lowe *et al.* 2000). While there is considerable inshore/offshore movement of Atka mackerel for spawning and feeding within this depth limit, there is no evidence of a net seasonal movement of Atka mackerel biomass across critical habitat boundaries and the total distribution of biomass is essentially uniform (L. Fritz and S. McDermott, NMFS Alaska Fisheries Science Center, unpublished data).

Given the relationship between critical habitat and Atka mackerel habitat and the assumption of relatively uniform distribution of biomass it was estimated that, on average, approximately two-thirds of the Atka mackerel population is inside critical habitat in the Aleutian Islands on a monthly basis. Approximately 68.8% of the Aleutian Islands shelf area, the effective limit of Atka mackerel habitat, is inside critical habitat for Steller sea lions (NMFS 1998g, Figure 11). Monthly Atka mackerel biomass estimates within critical habitat were obtained by the following method. The January 1995 estimate was 67% of the age 3+ biomass for 1995, as shown in Table 3.2-4 (Lowe and Fritz 1999). This was converted to numbers by assuming an average weight of 1 kg per fish. Numbers were then decayed by 1/12 of M ($M=0.3$) each month for the year, and increased by 1/12 of the difference between current year and next year's biomass to account for recruitment. These calculations were done for February-December each year, and the January estimate for the following year was 2/3 of the age 3+ begin-year biomass. The "average" year was based on the average of the monthly estimates of biomass in critical habitat (not subtracting catch) from January 1995-December 1999 (Table 3.2-5).

Table 3.2-4. Estimates of begin-year age 3+ Atka mackerel biomass in the Aleutian Islands in 1995-2000 (thousands of mt).

Year	Biomass in the Aleutian Islands			Biomass in Critical Habitat		
	Mean	-95%	0.95	Mean	-95%	0.95
1995	1,016	660	1,372	681	442	919
1996	846	550	1,143	567	368	765
1997	679	441	917	455	296	614
1998	614	399	829	411	267	555
1999	588	382	794	394	256	532
2000	565	367	763	379	246	511

95th percentile confidence limits ($\pm 35\%$ of the mean) were estimated from the mean of the 1997 Aleutian Islands groundfish trawl survey. Estimates of critical habitat mean biomass and confidence limits are 2/3 of the Aleutian Island estimates.

Table 3.2-5. Average age 3+ Atka mackerel biomass (mt) in critical habitat by month for 1995-1999 and 95% confidence limits (+/- 35% of the mean).

Month	Average	-95%	+95%
Jan	501,589	326,033	677,145
Feb	494,239	321,255	667,223
Mar	487,071	316,596	657,545
Apr	480,079	312,052	648,107
May	473,261	307,619	638,902
Jun	466,610	303,297	629,924
Jul	460,124	299,081	621,168
Aug	453,798	294,969	612,627
Sep	447,628	290,958	604,298
Oct	441,611	287,047	596,175
Nov	435,742	283,232	588,252
Dec	430,018	279,512	580,524

The estimated 95% confidence limits in Tables 3.2-4 and 3.2-5 are based solely on the variance of the 1997 bottom trawl survey biomass estimate for Atka mackerel in the Aleutian Islands. For this survey, the difference between the mean and each upper and lower confidence limit was 35% of the mean, which served as the estimate of the confidence limit. This is a conservative estimate of the real confidence limits (which are larger), since variance around the survey biomass estimate is only one of many components of the true variance.

No reliable estimate exists of current Atka mackerel biomass in the GOA. Atka mackerel have not been commonly caught in the GOA triennial trawl surveys. It has been determined that the general GOA groundfish bottom trawl survey does not assess the GOA portion of the Atka mackerel stock well, and resulting biomass estimates have little value as absolute estimates of abundance or as indices of trend (Lowe and Fritz 2000). Because of this lack of fundamental abundance information, GOA Atka mackerel are not assessed with a model. The stock assessment that consists of descriptions of catch history, length and age distributions from the fishery (1990–1994) and length and age distributions from the trawl surveys (1990, 1993, and 1996). This information is presented in the GOA Atka mackerel stock assessment, which is incorporated into the GOA SAFE report.

Age and size distributions of GOA Atka mackerel are discussed by Lowe and Fritz (2000). The most recent size and age distributions are from the 1996 and 1993 trawl surveys, respectively. Male and female size distributions had mean lengths of 45 and 47 cm, respectively, indicating the population is skewed towards the 1988 year class. It appears as though little recent recruitment has occurred in the GOA population.

Acceptable Biological Catch as Recommended in Most Recent Stock Assessments

In 2000, BSAI Atka mackerel fell into Tier 3a of the ABC and OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the OFL for BSAI Atka mackerel would be reached at 138,100 mt. The maximum allowable fishing mortality rate for ABC (F_{ABC}) is $F_{40\%}$, estimated to be 0.19 for Atka mackerel, which translated to a yield of 58,700 mt (Lowe *et al.* 2000). In 2000, the stock assessment ABC recommendation for the 2001 Atka mackerel fishery was

below the maximum rate prescribed under Tier 3a, to provide a more risk averse harvest rate and to accommodate uncertainty. The stock assessment F_{ABC} is 0.35, which translated to a yield of 108,100 mt. A recommendation lower than $F_{40\%}$ was recommended in the 1999 stock assessment because: (1) stock size as estimated by the age-structured analysis has declined since 1991; and (2) the 1997 Aleutian trawl survey biomass estimate fell to roughly 50 percent of the 1992 and 1994 estimates. The stock biomass increased somewhat in the 2000 survey driven by a strong 1998 year class.

There is currently no reliable estimate of current GOA Atka mackerel biomass. Therefore, GOA Atka mackerel fall under Tier 6 of Amendment 56 to the BSAI and GOA Groundfish FMPs. Under Tier 6, OFL level is defined as the average catch from 1978 to 1995, and ABC is defined as not exceeding 75 percent of OFL. The average annual catch from 1978 to 1995 is 6,200 mt; thus ABC cannot exceed 4,700 mt. Given the uncertainty regarding stock size, the current ABC recommendation from the stock assessment is below the maximum prescribed under Tier 6 providing a very conservative harvest strategy. The 2000 stock assessment for the 2001 fishery recommended an ABC of 600 mt, with the intention of precluding a directed fishery, but providing for bycatch needs in other trawl fisheries. An ABC lower than the maximum prescribed under Tier 6 was recommended for the following reasons.

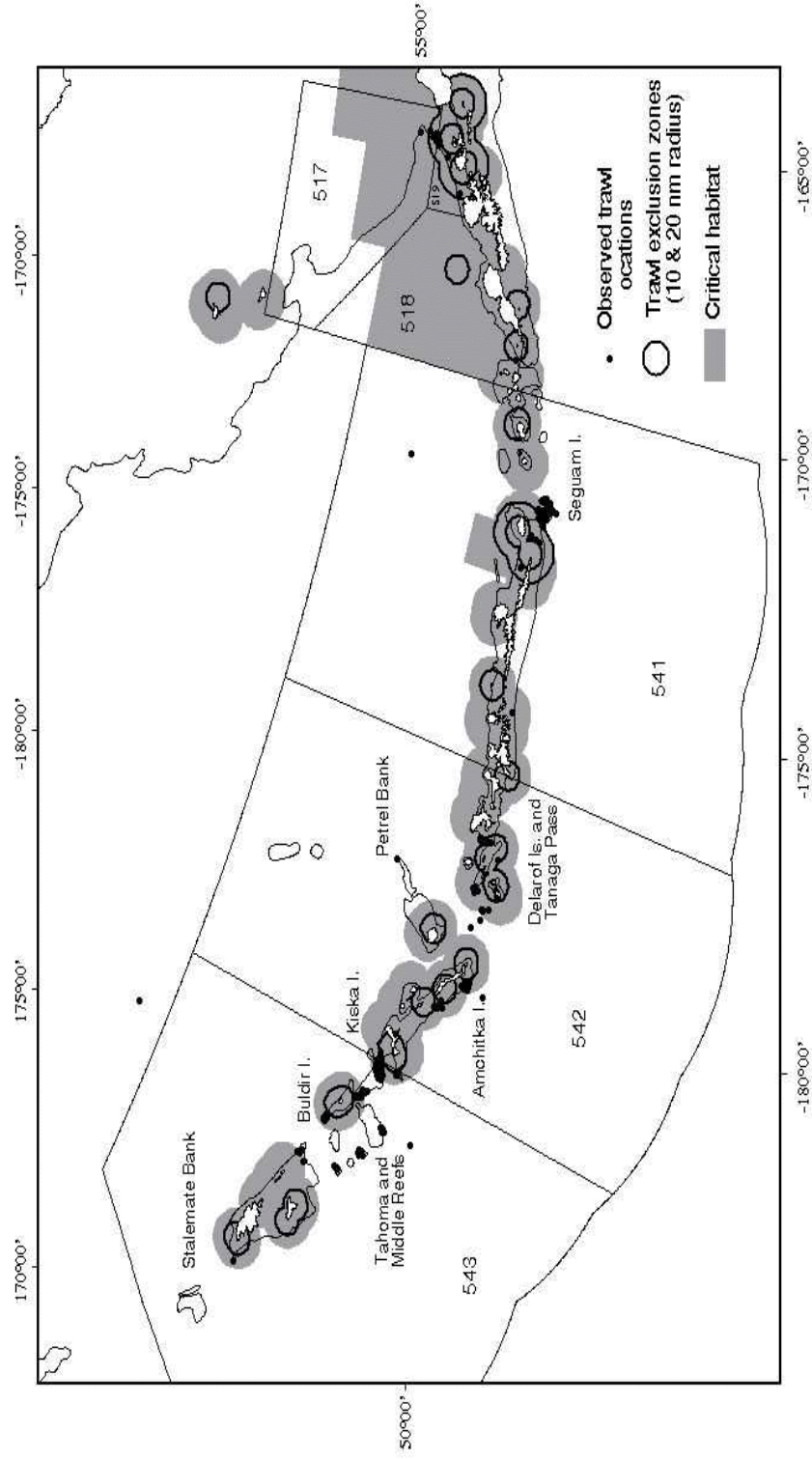
1. The GOA Atka mackerel population appears to be particularly vulnerable to fishing pressure because of sporadic movement of fish eastward from the Aleutian Islands.
2. There is currently a high level of uncertainty regarding the size of the population.
3. It has been shown that the GOA Atka mackerel fishery might have created localized depletions at catch levels lower than the estimated ABC of 4,700 mt. These localized depletions may have reduced foraging success for Steller sea lions (Lowe and Fritz 1996).
4. Analyses of local fishery catch per unit of effort (CPUE) indicated that Atka mackerel populations may have declined significantly between 1992 and 1994 (Lowe and Fritz 1996), reflecting the trend of the Aleutian Islands Atka mackerel population during that period, which continued declined through 1994 before rebounding somewhat in 2000 (Lowe *et al.* 2000).

Estimated OFLs, ABCs, and TACs for Atka mackerel in the BSAI and GOA for 2001, and TAC figures for 2000 are shown in Table 3.2-6.

Table 3.2-6 Estimated Overfishing Levels (OFL), Acceptable Biological Catch (ABC), and Total Acceptable Catch (TAC) for Atka Mackerel in the BSAI and GOA for 2001, and Total Catch Figures for 2000, by Area (all values in metric tons)

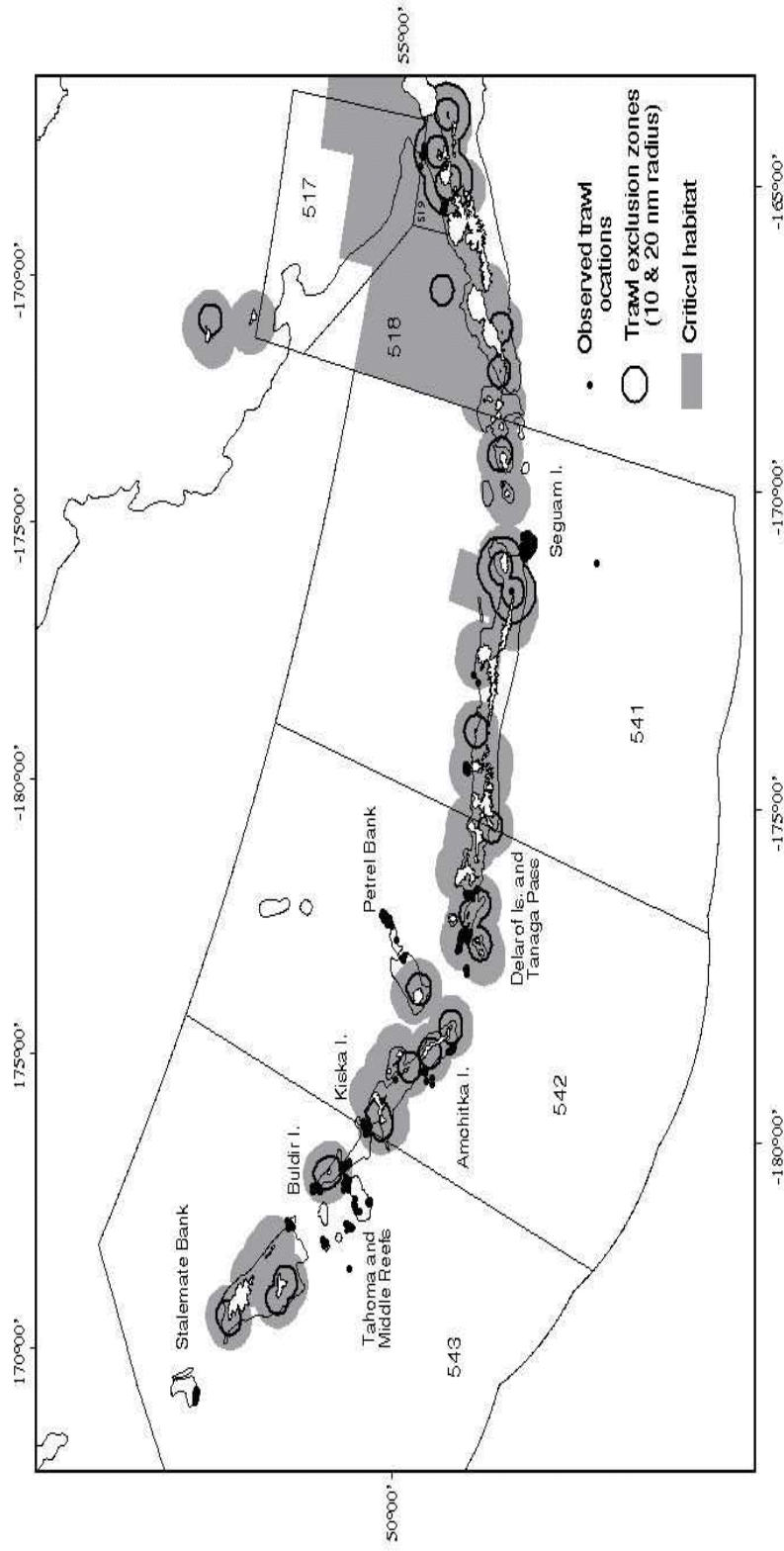
Area	OFL	ABC	TAC	2000 Catch
Bering Sea/ Aleutian Islands	138,100	69,000	69,300	42,394
Gulf of Alaska	6,200	600	600	170

Figure 3.2-3 Observed Atka mackerel fishery locations in the Aleutian Islands region in 1998. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200-m isobath, management Areas 541–543, and names of locations fished are shown.



Source: NMFS

Figure 3.2-4 Observed Atka mackerel fishery locations in the Aleutian Islands region in 1999. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200-m isobath, management Areas 541-543, and names of locations fished are shown.



Source: NMFS

3.2.4 Flatfish

Several species of flatfish occurring in the BSAI and GOA are currently targeted in the Alaska groundfish fishery. However, none of these species are directly affected by proposed management changes under the Draft SSL Protection Alternatives. However, these fisheries may be impacted by management changes for pollock, Pacific cod, and Atka mackerel. Because flatfish are not directly addressed by this SEIS, they are not described in detail here. Detailed information on life history, trophic interactions, fisheries, stock assessment, and ABC recommendations for each species or complex are provided in the Draft Programmatic SEIS (NMFS 2001a), and the Stock Assessment and Fishery Evaluation reports for the BSAI and GOA (NPFMC 2000c, 2000d).

Flatfish species are by nature demersal, and frequent variable habitat types depending on species. Flatfish are of variable importance as prey for Steller sea lions, ranging from a minor prey item to a significant diet component near specific haulout areas and rookeries in terms of frequency of occurrence (FO). Arrowtooth flounder has an increasing FO in Steller sea lion diets in the western GOA (see Section 3.1.1.7), which reflects the increasing abundance of this flatfish species.

For the purpose of this SEIS, target flatfish species are grouped based on the availability and suitability of information to identify the level of direct, indirect, and cumulative effect of the alternatives analyzed in this SEIS. Flatfish species with a greater degree of available information are yellowfin sole (*Limanda aspera*), rock sole (*Lepidopsetta bilineata*), flathead sole (*Hippoglossus elassodon*), Greenland turbot (*Reinhardtius hippoglossoides*), arrowtooth flounder (*Reinhardtius stomais*), and Alaska plaice (*Pleuronectes quadriterculatus*), in the BSAI, and arrowtooth flounder in the GOA. Under the current management regime (Alternative 1) Bering Sea flatfish are classified under Tier 3 of the ABC/OFL definitions. For each flatfish species in the FMP, the 2001 TAC was set at a level lower than the ABC. Harvest is further restricted by halibut bycatch limits (with the exception of yellowfin sole in recent years) where fisheries have been closed before reaching the TAC because of halibut bycatch limits.

Flatfish with more limited information include: the “other flatfish” complex in the BSAI (excluding Alaska plaice), and shallow and deep water flatfish, and flathead sole in the GOA. The BSAI “other flatfish” complex as described here includes rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulus*), butter sole (*Iopsetta isolepis*), sand sole (*Psettichthys melanostictus*), and deepsea sole (*Embassichthys bathybius*). These stocks are managed under a Tier 4, 5, or 6 harvest strategy per as appropriate to the available level of data on stock structure and biomass. ABC determinations for these species are detailed in the 2000 SAFE Reports (NMFS 2001c, 2001d).

Flatfish species comprise a large proportion of the exploitable groundfish biomass in the BSAI and the GOA. These fisheries are typically prosecuted by bottom trawlers, with the exception of BSAI Greenland turbot fishery. Longlines have become the dominant gear type for this species since the early 1990s. No halibut bycatch has been apportioned to the Greenland turbot trawl fishery since 1996, effectively prohibiting this gear type. The “other flatfish” species, with the exception of Alaska plaice, are not harvested economically, but are taken as bycatch in other high value trawl fisheries. In general, the biomass of flatfish in the BSAI remains high, following significant population expansions and high recruitment levels throughout the 1980s. Greenland turbot is an exception. Biomass for this species has declined from the 1981 through 1997 due to a series of poor year classes. Recruitment for many of the flatfish species in both the GOA and BSAI has been declining in recent years, and stock declines are predicted in the future as a consequence. Fisheries have not harvested the exploitable biomass of any flatfish species or complex in the BSAI for several years due

to bycatch limits on halibut and crab and conservative quotas. In the GOA, arrowtooth flounder biomass is currently at peak levels and the fishery is experiencing increasing economic development. From NMFS catch data it shows the remaining flatfish species are not fully harvested due to bycatch limits on halibut.

3.2.5 Rockfish

At least 32 rockfish species of the genera *Sebastes* and *Sebastolobus* have been reported to occur in the GOA and BSAI (Eschmeyer *et al.* 1984), and several of them are of commercial importance. Pacific ocean perch (*Sebastes alutus*) has historically been the most abundant rockfish species in the region and has contributed most to the commercial rockfish catch. Other species such as northern rockfish (*S. polyspinis*), rougheye rockfish (*S. aleutianus*), shortraker rockfish (*S. borealis*), shortspine thornyheads (*Sebastolobus alascanus*), yelloweye rockfish (*ruberrimus*), and dusky rockfish (*S. ciliatus*) are also important to the overall rockfish catches. Rockfish are long lived species, with maximum ages ranging from 60 to 140 years depending on the species. They are slow growing, reaching maturity after periods ranging from

Rockfish are all demersal species which do not tend to form dense aggregations. The rockfish complex was commonly found in the Steller sea lion diet prior to the 1970s but is currently a significant prey item, having a FO of less than 5 percent in recent studies. The overall catch of rockfish in the BSAI and GOA is relatively low in comparison to other groundfish species. Rockfish TACs are generally not fully exploited. Given the lack of importance of rockfish in SSL diet and relatively low levels of exploitation, they are not specific focus of the Draft SSL Protection Alternatives. Because of this lack of emphasis, the rockfish species are not described in detail here. More detailed information is available in the Draft Programmatic SEIS (NMFS 2001a) and the 2000 SAFE Reports (NPFMC 2000c, 2000d).

For the purpose of this SEIS, target rockfish species are grouped based on the availability and suitability of information to identify the level of direct, indirect, and cumulative effect of the alternatives analyzed in this SEIS. BSAI Pacific ocean perch (POP) are the most well known and are evaluated separately. Red rockfish (sharpchin, northern, rougheye, and shortraker) and other rockfish in the BSAI are evaluated as a group, and all GOA rockfish are evaluated as a group. Shortspine and longspine thornyheads (*Sebastolobus alascanus* and *Sebastolobus altivelis*, respectively) are treated separately and are described in the following section.

POP are the dominant species of red rockfish in the BSAI. They are caught primarily along the Aleutian Islands and to a lesser extent in the EBS. Biomass has increased significantly following heavy exploitation by foreign fisheries prior to 1978. POP, like all rockfish, is long lived and slow growing relative to many groundfish species, with an advanced age at maturity. These factors make the population vulnerable to overfishing. Given these life history characteristics and past fishing history, they are conservatively managed. POP currently fall under Tier 3a of the ABC/OFL definitions, which equates to an ABC of 10,200 mt for the AI and 1,700 mt for the eastern Bering Sea.

Little is known about the other red rockfish (ORR) and other rockfish complexes in the BSAI. These stock complexes were developed to separate management of the commercially valuable POP and ORR species, and to avoid overfishing of any one stock in the complex. Further division of the ORR complex is being established to provide further management protection. The ORR and other rockfish complexes are managed under Tier 5 of the ABC/OFL definitions. The combined OFL for the group for 2001 under Tier 5 is 11,700 mt. The ABC/TAC for the combined group is set at 8,800 mt.

Rockfish in the GOA include at least 30 species which have been organized into three management assemblages based on habitat and distribution: demersal shelf rockfish, pelagic shelf rockfish, and slope

rockfish. The slope rockfish assemblage has been subdivided to manage POP, northern, and rougheye and sharpchin rockfish separately from other species. A 1998 prohibition on trawling east of 140° W longitude affected rockfish fisheries that are now prohibited in the East Yakutat/Southeast Outside area of the eastern GOA. All rockfish species in the GOA are similarly affected by the Draft SSL Protection Alternatives and are evaluated as a group in this EIS. GOA rockfish are managed under either Tier 3, 4 or Tier 5 of the ABC/OFL definitions, depending on the level of knowledge of the species complex. The POP stock is the primary species in the slope rockfish group. POP is currently rebounding from a period of low abundance in the 1980s, with strong year classes contributing to recent abundance. However, the spawning stock is currently below the $B_{40\%}$ level. The recommended ABC for the stock complex in 2001 is 13,510 mt. For pelagic shelf rockfish, the recommended ABC for 2001 is 5,980 mt. The ABC/TAC recommendations for demersal shelf rockfish are keyed to the abundance of yelloweye rockfish. The recommended ABC for the stock complex in 2001 is 330 mt (NPFMC 2000d). Most of the GOA rockfish harvest in 2000 was below TACs, although harvest for some species with low TAC levels did exceed TAC.

3.2.6 Thornyheads

Thornyheads in Alaskan waters are comprised of two species, the shortspine thornyhead and the longspine thornyhead, close relatives to the rockfish. As with rockfish, no changes to the thornyhead fishery are proposed under this SEIS, and any impacts on the fishery are indirect results of changes in the management of pollock, Pacific cod, and Atka mackerel. Because thornyheads are not directly addressed by this SEIS, they are described in less detail than pollock, cod, and Atka mackerel. Detailed information on life history, trophic interactions, fisheries, stock assessment, and ABC recommendations for each species or complex are provided in the Draft Programmatic SEIS (NMFS 2001a), and the SAFE Reports for the BSAI and GOA (NPFMC 2000c, 2000d).

Only the shortspine thornyhead is of commercial importance. It is a demersal species found in deep water, from 93 m to 1,460 m, from the Bering Sea to Baja California (Ianelli and Gaichas 1999). This species is not identified as a principal prey item of Steller sea lions or other marine mammals. Little is known about thornyhead life history. Like other rockfish, they are long-lived and slow growing. The maximum recorded age is probably in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 and a length of about 21 cm. Thornyheads spawn large masses of buoyant eggs during the late winter and early spring (Pearcy 1962). Juveniles are pelagic for the first year. Yang (1993, 1996) showed that shrimp were the top prey item for shortspine thornyheads in the GOA, while cottids were the most important prey item in the Aleutian Islands. Biologically, the greatest area of uncertainty for this species is in their longevity and natural mortality rate. Currently, NMFS scientists believe they are slow-growing and long-lived fish that are relatively sedentary on the ocean floor. Survey and fishery catch rates indicate that they are relatively evenly distributed within their habitat and, like many other groundfish species, do not tend to form dense aggregations.

Until recently, thornyheads were not targeted by the commercial fishery. However, they are now among the most valuable rockfish species and are harvested by trawl and longline gear. Most of the domestic harvest is exported to Japan. Thornyheads are taken with some frequency in the longline fishery for sablefish and cod, and are often part of the bycatch of trawlers concentrating on pollock and other rockfish species. In the GOA, shortspine thornyheads are assessed with an age-structured model incorporating data from two fisheries (longline and trawl) and two types of survey data. Surveys used to assess this species are described in Section 2.7.3 of the Draft Programmatic SEIS (NMFS 2001a). The estimated biomass in 2000 was 23,084 mt, and the recommended ABC/TAC for 2000 was 2,310 mt. A stock assessment was not performed for

thornyheads in 2000 due to limited data. Therefore same the ABC and TAC levels for 2000 were adopted for 2001.

In the BSAI, thornyheads are managed as the primary species in, the other rockfish management assemblage. The assessment is based on the most recent catch and survey data. Thornyheads are currently managed under Tier 5 harvest strategy. The best estimate of complex-wide biomass under Tier 5 results in recommended ABCs of 361 mt in the eastern Bering Sea and 676 mt in the Aleutian Islands for 2001. Recommended OFLs under Tier 5 for 2001 are 482 mt in the EBS and 901 mt in the Aleutian Islands.

3.2.7 Sablefish

Sablefish (*Anoploma fimbria*) are found from northern Mexico to the GOA, westward to the Aleutian Islands. The directed fishery for sablefish is conducted by longliners, with this gear type accounting for approximately 90 percent of the total catch. Trawlers also catch sablefish as bycatch in other fisheries. A minimal amount of sablefish is caught by pot boats. The directed fishery occurs on the upper continental slope and a few deep water gullies, the areas inhabited by adult sablefish. As with flatfish, rockfish, and thornyheads, no changes to the sablefish fishery are proposed under this SEIS, and any impacts on the fishery are indirect results of changes in the management of pollock, Pacific cod, and Atka mackerel. Because sablefish are not directly addressed by this SEIS, it is not described in detail here. More detailed information on life history, trophic interactions, fisheries, stock assessment, and ABC recommendations sablefish are provided in the Draft Programmatic SEIS (NMFS 2001a), and the Stock Assessment and Fishery Evaluation reports for the BSAI and GOA (NPFMC 2000c, 2000d).

Sablefish are not identified as a significant prey item for Steller sea lions, most probably due to their deep water distribution and demersal nature as adults. They are typically found in gullies and deep fjords at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). Studies have shown sablefish to be highly migratory for at least part of their life cycle, and substantial movement between the BSAI and the GOA has been documented (Heifetz and Fujioka 1991; Maloney and Heifetz 1997). Adults reach maturity at 4 to 5 years and a length of 51 to 54 cm (McFarlane and Beamish 1990). Sablefish are long-lived, with a maximum recorded age in Alaska of 62 years (Sigler *et al.* 1997). Spawning is pelagic and occurs at depths of 300–500 m near the edges of the continental slope (McFarlane and Nagata 1988). Juveniles are pelagic and appear to move into comparatively shallow nearshore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). It appears that sablefish are opportunistic feeders, with some studies showing a diet primarily composed of fish, while other studies have found a diet dominated by euphausiids (Laidig *et al.* 1997; Tanasichuk 1997). Sablefish prey includes variety of benthic invertebrates, benthic fishes, as well as squid, mesopelagic fishes, jellyfish, and fishery discards. Larval sablefish feed on a variety of small zooplankton, ranging from copepod nauplii to small amphipods, while young juveniles feed primarily on large zooplankton and euphausiids. Gadid fish (mainly pollock) comprise a large part of the sablefish diet. Young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the southeast Alaska troll fishery during the late summer. Nearshore residence during their second year provides the opportunity to feed on young salmon during the summer months. This near shore residency may make juvenile sablefish available as occasional prey for Steller sea lions.

Due to their migratory nature, Alaskan sablefish are considered a single stock and assessed in a combined area (BSAI and GOA) with an age-structured model incorporating fishery and survey catch data and age and length compositions. Survey data come from annual sablefish longline surveys in the GOA, and biennial longline surveys in the BSAI. These surveys indicate that the stock size peaked in the mid-1980s because of

a series of strong years and has declined to lower levels ever since. Declining abundance is due to insufficient recruitment to replace strong year classes from the later 1970s, which are dying off. The estimated mean age of the recruited portion of the population is 7.3 years. The stock is currently stable at a relatively low abundance (Sigler *et al.* 2000).

Sablefish fall into Tier 3 of the ABC and OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. The ABC for 2001 considers the declining trend evident in the population and is conservatively recommended at 16,900 mt for the combined BSAI/GOA stock (Sigler *et al.* 2000).

3.2.8 Squid and Other Species

In the BSAI Groundfish Fisheries Management Plan, species of squid and sculpin, skate, shark, and octopi which occur in the fishery are managed collectively as the squid and other species group. These species are aggregated for management because insufficient data exist to manage each of the other species groups separately. None of the species in the squid and other species category are currently targeted by the BSAI and GOA groundfish fisheries. None of these species are directly affected by management changes under this SEIS, however, changes in the spatial and temporal distribution of pollock, Pacific cod and Atka mackerel fisheries could impact bycatch rates in some cases. Because the complex is not directly addressed by this SEIS, it is not described in detail here. More detailed information on life history, trophic interactions, fisheries, stock assessment, and ABC recommendations for the complex is provided in the Draft Programmatic SEIS (NMFS 2001a), and the Stock Assessment and Fishery Evaluation reports for the BSAI and GOA (NPFMC 2000c, 2000d).

Red armhook squid (*Berryteuthis magister*) predominates in commercial catches in the EBS and GOA, and *Onychoteuthis borealijaponicus* is the principal species encountered in the Aleutian Islands. Forty-one sculpins species were identified in the EBS and 22 species in the Aleutian Islands (Bakkala 1993; Bakkala *et al.* 1985; Ronholt *et al.* 1985). During these same surveys, 15 skate species were identified, but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist. Species that have been consistently identified during surveys are the Alaska skate (*Bathyraja parmifera*), big skate (*Raja binoculata*), longnose skate (*R. rhina*), starry skate (*R. stellulata*), and Aleutian skate (*B. aleutica*). Many species in the squid and other species assemblage are important prey for marine mammals and birds, as well as commercial groundfish species. Squid, octopus, sculpins, and skates are occasional prey for Steller sea lions. However, around some Steller sea lion rookery and haulout areas these species may be predominant prey items (see Section 3.1.1.7). Evidence exists that Pacific sleeper sharks (*Somniosus pacificus*) occasionally prey on Steller sea lions (Section 3.1.1.7).

Assessment data are not available for squid from NMFS surveys because of their mainly pelagic distribution over deep water. Information on the distribution, abundance, and biology of squid stocks in the EBS and Aleutian Islands is generally lacking. While biomass estimates have been made for sharks and octopuses, the NMFS bottom trawl surveys are not designed to adequately sample the realms they inhabit. Sharks are rarely taken during demersal trawl surveys in the Bering Sea; however, spiny dogfish (*Squalus acanthias*) is a species usually caught, and the Pacific sleeper shark has been taken on occasion. Two octopus species have been recorded: *Octopus dofleini* is the principal species, *Opisthoteuthis californica* appears only intermittently.

Data from NMFS bottom trawl and EIT surveys provide the only abundance estimates for the various groups and species comprising the other species category. Stock assessments using these data are described in detail in the Draft Programmatic SEIS (NMFS 2001a) and the 2000 SAFE Report for the BSAI (Fritz 2000). The

estimated biomass of other species for 2000, excluding squid, was 566,900 mt. Skates represent 30 to 40 percent of the other species biomass from all surveys and are the most common species in each year except 1984 when sculpin biomass was highest within the category. Total biomass for the other species category increased between 1984 and 2000. This is the result of apparent increases in skate, shark, and smelt biomass, some of which may be difficult to resolve from changes in survey efficiency. Sculpin biomass appears relatively stable over this period. No reliable biomass estimates for squid exist, and no stock assessment *per se*. Sobolevsky (1996) cites an estimate of 4 million tons for the entire Bering Sea made by squid biologists at the Pacific Research Institute of Fisheries and Oceanography (Shuntov 1993), and an estimated 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. NMFS bottom trawl surveys almost certainly underestimate squid abundance.

Squid catches and ABCs are inferred to be a very small percentage of the total squid biomass in the EBS and GOA. BSAI squid ABC and OFL are set using criteria in Tier 6, as described in Amendment 44 to the BSAI FMP, given the lack of data on squid population dynamics and biomass. OFL is set equal to the average annual catch from 1978 to 1995 (2,624 mt), while ABC is capped at no greater than 75 percent of OFL. This equates to an ABC of 1,970 mt. The ABC and TAC for BSAI squid are set at this level for 2001. OFL and ABC values will remain constant unless management changes for squid are proposed by the Council.

The remaining species in the Other Species category are managed under Tier 5 of the OFL/ABC definitions. Using Tier 5 criteria, ABC is capped at 75 percent of OFL. Recent interest in developing fisheries for some species in this complex resulted in increases in ABCs beyond these criteria in recent years. For the 2000 fishery, the Council capped the ABC at a level approximately 10 percent higher than the ABC recommendation in the 1999 SAFE Report. BSAI other species TAC has been set equal to the other species ABC by the Council. The 2001 ABC for the BSAI other species category set using this process is 26,500 mt. This equates to an exploitation rate of about 5 percent of the best estimate of current biomass, set at 566,900 mt. The annual TAC for GOA Squid and Other Species for 2001 is set equal to 5 percent of the sum of all GOA groundfish TACs, which equates to 13,619 mt. Catches of other species in the GOA ranged between 1,570 mt and 6,867 mt from 1990 to 2000.

3.3 Non-specified Fish Species

This category include those fish, invertebrates, and other organisms which are not included in BSAI and GOA FMPs, primarily because of their minor commercial importance or in some cases because they are managed by the State of Alaska. Non-specified species (not including species prohibited in the groundfish fisheries off Alaska such as salmon, herring, and crab) managed by the state include sea urchins, sea cucumbers, clams, shrimp, scallop, lingcod, black rockfish, and blue rockfish. These species are managed by ADF&G and the fisheries are described by Kruse et al (2000) in their report titled "Overview of State-Managed Marine Fisheries in the Central and Western Gulf of Alaska, Aleutian Islands, and Southeastern Bering Sea, with Reference to Steller Sea Lions." There are some data collected for non-specified species using small mesh and bottom trawl surveys and zooplankton surveys but biomass estimates are not available for most non-specified species for all of the BSAI and GOA (NMFS 2001a). The draft SEIS (NMFS 2001a) and the 2001 Ecosystem Considerations (NPFMC 2000c, appendix D) provides the latest regarding research and current status for non-specified species and is summarized in this section.

These species comprise critical trophic levels in the marine ecosystem. The presence or absence of such indicator species as corals and sponges can be used to help describe the diversity of benthic marine communities being considered for further conservation measures. Due to the small size of most of these

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